COMBUSTION

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Vol. 10, No. 4 | OCTOBER, 1938 | 25c a copy

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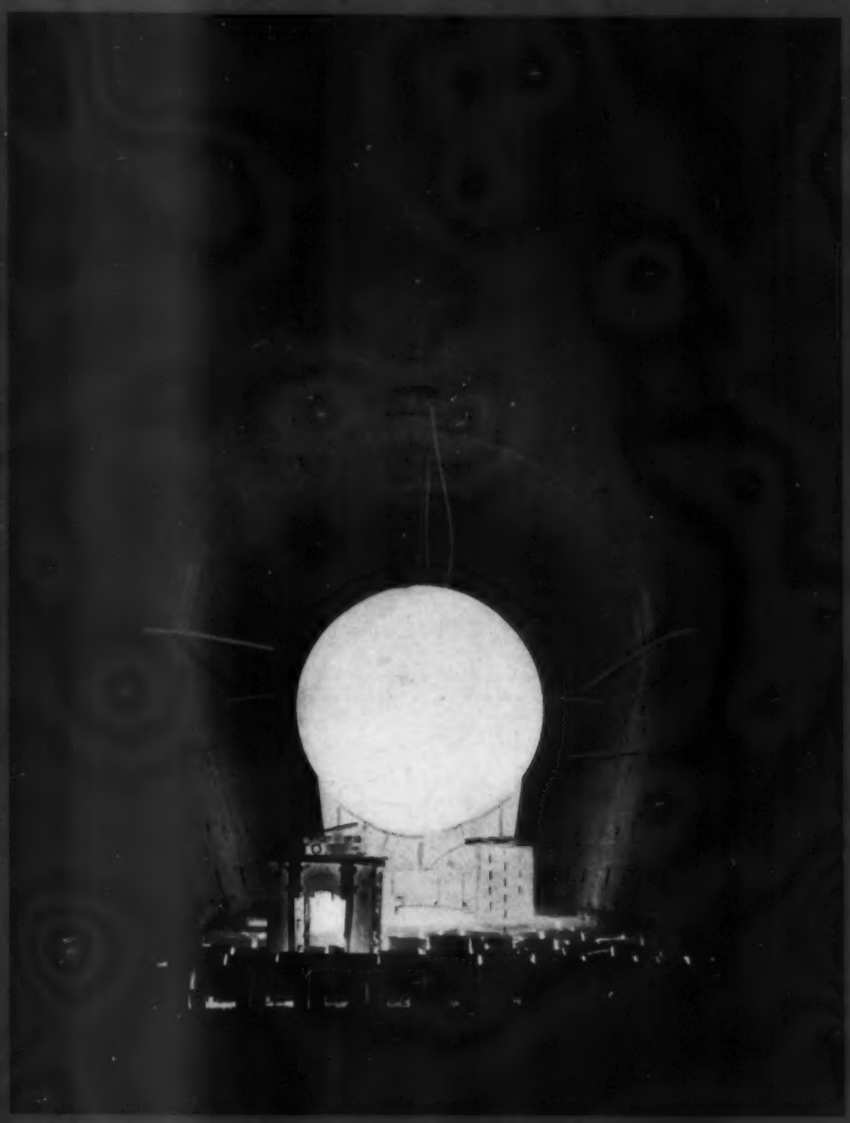
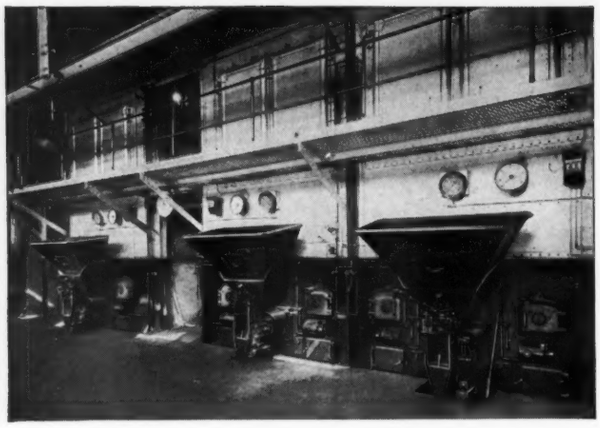


To check your guess as to what this photograph shows, see page 31

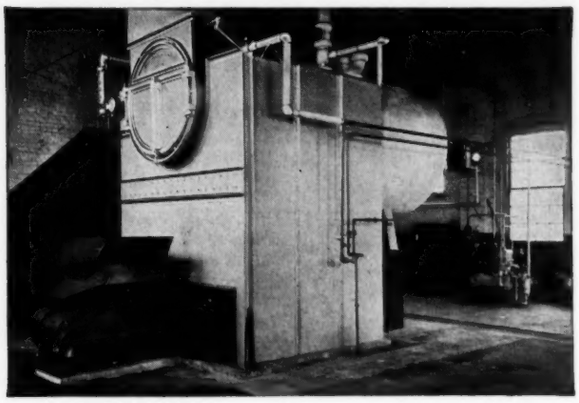
Steam and Power Costs Reduced at A. E. Staley Plant

Considerations Affecting Selection of Pulverizers

Lubrication of Power Plant Auxiliaries

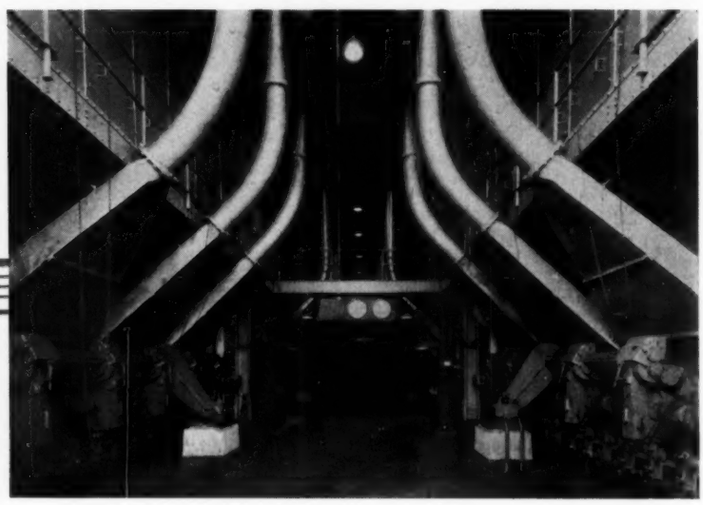


C-E Underfeed Stoker (Type E)—Single-retort design—for boilers from 150 to 600 rated horsepower.



C-E Skelly Stoker Unit—Center-retort or Side-retort design—for boilers up to 200 rated horsepower.

(Right) C-E Underfeed Stoker—Multiple-retort design—for boilers from 400 rated horsepower up.



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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME TEN NUMBER FOUR

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Combustion is published monthly by Combustion Publishing Company, Inc., a subsidiary of Combustion Engineering Company, Inc., 200 Madison Avenue, New York. Frederic A. Schaff, President; Charles McDonough, Vice-President; H. H. Berry, Treasurer; G. W. Grove, Secretary. It is sent gratis to consulting and designing engineers and those in charge of steam plants from 500 rated boiler horsepower up. To others the subscription rate, including postage, is $2 in the United States, $2.50 in Canada and Great Britain and $3 in other countries. Single copies: 25 cents. Copyright, 1938 by Combustion Publishing Company, Inc. Printed in U. S. A. Publication office, 200 Madison Avenue, New York. Issued the middle of the month of publication.

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PARTIAL LIST OF ORDERS RECEIVED

FOR THE NEW COPES FLOWMATIC REGULATOR

USER AND LOCATION	DATE	BOILER DATA NO.	MAKE	WSP LB.	MAX. EVAP. LB./HR.
Canadian steel mill	1937	1	Freyn	130	25,000
Canadian steel mill	1938	1	B & W	450	120,000
Connecticut industrial plant	1937	2	Riley	700	90,000
Illinois industrial plant	1937	2	Riley	700	90,000
Kansas utility plant	1938	2	F-W	650	70,000
Maryland textile mill	1937	2	Riley	450	200,000
Michigan chemical plant	1938	1	F-W	1325	300,000
Michigan paper mill	1937	1	Baden.	550	110,000
Michigan rubber company	1937	3	Lasker	450	20,000
Michigan utility plant	1937	1	B & W	850	400,000
Michigan utility plant	1938	1	F-W	875	400,000
Missouri utility plant	1938	1	B & W	225	120,000
and	1938	2	W & W	180	110,000
Nebraska utility plant	1937	3	B & W	400	140,000

USER AND LOCATION	DATE	BOILER DATA NO.	MAKE	WSP LB.	MAX. EVAP. LB./HR.
Nebraska utility plant	1938	2	C-E	475	200,000
New Jersey industrial plant	1938	1*	C-E	400	50,000
New York brewery	1938	3	C-E	410	75,000
New York industrial plant	1938	1	Baden.	650	100,000
Ohio steel mill	1938	2*	B & W	415	330,000
Ohio textile mill	1937	1	Vogt	150	85,000
Pennsylvania industrial plant	1938	1	Vogt	450	100,000
Pennsylvania paper mill	1937	1	Spgfld.	600	100,000
Pennsylvania steel mill	1938	1*	B & W	400	85,000
Pennsylvania utility plant	1937	1	B & W	675	200,000
Pennsylvania utility plant	1938	1	F-W	875	400,000
Texas chemical plant	1937	1	B & W	400	200,000
Texas oil refinery	1937	1*	Riley	600	350,000
Virginia paper mill	1938	2	B & W	450	120,000

*Two COPES Flowmatic Regulators purchased for each boiler.

Name of any user listed above will be furnished on request.

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EDITORIAL

Intangible Factors Discount Evaluations

Usually, proposals for power plant equipment involve one of three procedures. The purchaser may offer very general specifications, in which case the contract is likely to be awarded on price with less regard to the most economical design. Again, the specifications, based on the purchaser's experience or preference, may be so rigid as to preclude arrangements that would prove more desirable in the light of the manufacturer's diversified experience. However, in some such cases the way is left open to modifications suggested by the latter. Or, the specifications may be drawn up after collaboration with the manufacturers' representatives, in which case the most suitable arrangement is likely to be had and considerations of first cost become secondary to economical design. With the long useful life of such equipment operating savings and flexibility frequently offset differences in initial cost by a large margin.

In selecting steam generating equipment it is the practice of many engineers to evaluate various factors, both as to fixed charges and anticipated operating costs. This is sound, providing such analysis is tempered with proper judgment as to maintenance and possible operating difficulties such as may incur outage far outweighing other evaluated savings. In a period of rapid development and changing practice, such as has been witnessed during the past few years, this assumes added importance. Hence, apparent savings on paper may be misleading.

For example, undue stress is sometimes placed on draft loss as reflected in fan power; tolerances in fan capacity to allow for conditions obtaining after continued operation may be discounted; a single pulverizer may be selected where two would insure greater reliability and flexibility; pulverizer capacity may be specified without considering future coals that may be burned; or a drum size may be stated that will just get by the immediate requirements. That is, allowances that may be regarded as insurance against inability to meet conditions encountered in the course of ordinary operation should not be penalized.

Despite the fact that present operating conditions require closer designing than formerly, it is the intangible factors that sometimes defy mathematical evaluations.

A Lesson from Paris

With so much loose talk current in this country as to the economic advisability of supplying many of our largest cities with power from remotely situated Federal hydro developments, it is pertinent to review briefly the situation that obtains in Paris. This was discussed in a recent paper by M. d'Harcourt before the French Association of Producers and Distributors of Electrical Energy.

From this it appears that the electrical supply of Paris is furnished by both steam and hydro power. The former represents a combined capacity of approximately a million kilowatts in stations situated within the city and its suburbs, whereas the latter is transmitted a distance of about three hundred miles from several water power plants in the Massif region in the South. Normally, about two hundred thousand kilowatts is thus transmitted, depending upon seasonal conditions.

Because of the variable character of the hydro power it is at times employed to carry only the peak of the load, whereas at other seasons it can serve the base load over the entire twenty-four hours. As peak power it has greater economic value because it replaces power that would otherwise have to be generated by the older and less efficient steam stations but as base load power it must be valued against that produced in the modern highly efficient steam stations.

Since 1935 there have been seventeen major interruptions on these transmission lines each involving loss in capacity of a hundred thousand kilowatts or more. Because of this it has been necessary to maintain at all times an active reserve of a hundred thousand kilowatts with its attendant standby charges. This represents fifty per cent of the hydro capacity and, in the opinion of the author, greatly reduces its economic value. While the French Government, of late, has encouraged hydro development, this has been due to other considerations.

Applying these lessons from Paris to conditions in this country, involving larger blocks of power from the huge Federal developments and vastly greater transmission distances, the magnitude of the required steam reserves becomes apparent. Furthermore, such power applied to the base load would be penalized by the costs and losses of such long distance transmission when compared with that produced by modern steam stations requiring less than a pound of coal per kilowatt-hour.

Savings through Welding

The Jury of Award for the Lincoln Foundation, which last month distributed $200,000 in cash prizes to 382 authors of papers on arc welding and listed many more for honorable mention, found that the aggregate savings claimed for this form of welding alone amounted to $1,600,000,000. It was not indicated over what period this saving would apply, probably because some of it had already been effected, some would apply to permanent structures and the remainder, perhaps the largest part, would be possible through the adoption of designs offered. The papers dealt with a wide variety of fields, including structural and transportation, machinery of many kinds and numerous fabricated products.

If one were to add the savings effected by other forms of welding, this amazing figure would be considerably amplified. It may be taken as a measure of the growth and importance of this relatively young branch of engineering.

Were it possible to assess the savings that have been brought about through welding as applied to the fabrication, installation and repair of power plant equipment, the figure would probably far exceed the most sanguine predictions.

Steam and Power Costs Reduced at A. E. Staley Plant

By JOHN C. KUHNS, Power Engineer
A. E. Staley Manufacturing Company

A brief review of the power developments at this plant over a period of years is followed by a description of the latest boiler and turbine installation rendered necessary in order to meet increasing steam and power demands, together with the most advantageous heat balance. This is a 400-lb pulverized-coal-fired installation which, as a whole, has effected a saving of approximately 40,000 tons of coal per year. Performance and maintenance figures are included.

THE A. E. Staley Manufacturing Company, Decatur, Ill., operates a wet milling corn products plant handling a maximum capacity of 50,000 bu of corn per day which is converted into primary products of corn syrups or starches with by-products of corn oil and gluten feed. Auxiliary operations include a soybean plant, dry milling 22,000 bu of soybeans per day and operating a 3,250,000-bu terminal grain elevator equipped with large grain dryers, also, a pumping station located about one and one-half miles from the main plant, which supplies from 10,000,000 to 22,000,000 gal of water per day for plant services.

The process is highly mechanized, involving about 2000 motors ranging from 1/4 hp to 250 hp, with about 15 hp as the average size. Naturally this involves quite a power load and the nature of the starch and corn syrup process, consisting largely of drying, evaporation and digester operations, makes a large demand for both high- and low-pressure steam.

This combination of power and steam demand renders imperative by-product power which is traditional with this industry. Many nice problems develop in maintaining a proper heat balance to follow increases in electrical loads and shifts in manufacturing processes, which frequently result in decreased demands for exhaust steam.

The original boiler pressure was 185-lb gage at which steam was delivered to both the turbine room and to process. In the former power was generated by turbine-generators running non-condensing and exhausting at 3-lb gage. Also, two 3600-cfm steam-driven air compressors exhaust into the 3-lb main. Distribution of process steam was at 185 lb, this pressure being reduced at the point of use in many departments. Throughout the plant all steam-driven equipment exhausts into the common exhaust main and all users of exhaust steam draw from it.

It was obvious early in the life of this plant that the logical fuel was the low grade screenings from the Springfield district; both because of the low cost of this fuel at the mine and the low freight rate.

In 1913 there was installed the first two 5580-sq ft long-drum boilers equipped with natural-draft stokers. These were followed in a short time by four more identical units, thus filling the original boiler house. Increased steam demands due to expansion of the plant led to an equal addition being built in 1919 to the west of the original boiler house in which ultimately six more identical boilers were installed, although the furnace volumes were increased by the boilers being set higher. These later boilers were fired by Coxe traveling grate stokers with forced draft and zoned air control, which showed such superior efficiency and capacity that stokers of this type were soon substituted for the original six natural-draft stokers.

Further increasing steam demand in 1924 brought another addition to the west, the only space available for expansion, designed to be filled with six more boilers of the same type as the first twelve but of larger size. The first two were installed as soon as the building was completed, each having 8970 sq ft of heating surface. These units were likewise fired by Coxe forced-draft stokers, but the stokers and furnace volumes were increased so that the ratio of coal burning capacity to heating surface was considerably greater than with the smaller boilers.

Boiler House 400 Ft Long

Almost as soon as the two larger boilers, identified as Nos. 13 and 14, had been installed, the total capacity of the boiler house was utilized and it became apparent that further additions would soon be necessary. As the boiler house was already 400 ft long and there were grave objections to further extensions, any means of securing greater capacity within the space provided in 1924 was looked upon with favor. About this time the Wood type steam generator, direct-fired with pulverized coal, was announced in this country and, as it offered double the amount of steam in the same floor space, it was decided to install an experimental unit which was put into operation in 1927 and known as No. 15.

After learning much from experience with the early design of this type of unit, and with steam demands still increasing, another direct-fired pulverized coal unit was designed, utilizing the same size and type of long-drum boiler as Nos. 13 and 14. This boiler, being the type for

which the bays were originally designed, fitted well into the existing structure. It was decided to get the maximum capacity from this unit and at the same time keep the heat release in the furnace as low as possible. Therefore, every expedient was employed to increase the furnace volume. The boiler was raised until the drums were just below the building girders. It was set back about three feet farther than the original design for a stoker unit while the furnace was extended toward the front completely to the firing aisle, thus providing a sort of dutch-oven effect for the burners with a water-cooled arch above them.

The furnace of this No. 16 unit is almost entirely water-cooled by fin-tube side walls and a V bottom. The rear wall construction is of bare tubes on boiler tube centers. A shadowed radiant superheater is located behind and between the rear wall tubes. Both this and No. 15 unit were equipped with plate-type air heaters and impact mills. However, while No. 15 has long flame burners located in each upper corner of the furnace, firing tangentially with a down draft, No. 16 has short flame horizontal turbulent burners firing through the front wall, near the bottom of the furnace.

No. 16 boiler was put into operation in the spring of 1929 and from that date records of operation and allocation of boiler house expense have been kept in considerable detail. During several subsequent years, although departments were added and electrical loads increased greatly, a good heat balance was maintained by the substitution of exhaust for live steam wherever practicable. Much was also done toward decreasing power demand by replacing old equipment with more efficient apparatus. By these means, during the past years, it has been possible to use all the exhaust steam from the power plant through the heating season and to keep the unavoidable losses in summer fairly low.

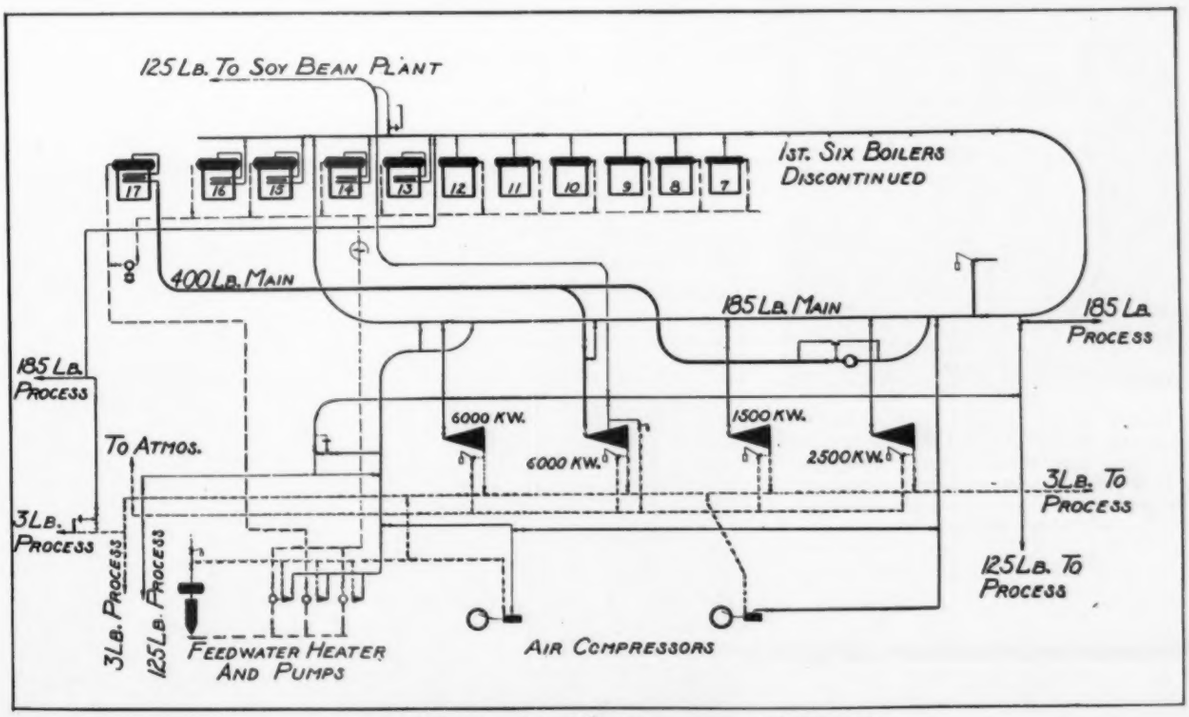
During the last few years, however, decreasing sugar production has lessened the demand for exhaust steam and a continual increase in mechanization, as well as the addition of new departments, culminated in an enormous increase of the soybean plant. This has a large power demand and no use for low-pressure steam, hence a situation developed which had to be met.

With the plant just on a balance, the additional 2000-kw demand for power, which had to be generated on the small, high steam rate turbines, would be blown to waste. This increased load also meant operating all three turbines, much of the time overloaded, and leaving nothing in reserve in case it became necessary to take a machine off the line for repairs or inspection.

Another cause of waste was due to large electrical loads during periods of shutdown of the corn plant. During these periods it is usually necessary to run certain departments and there is seldom any use at this time for the exhaust steam from the power that they require. When, on top of this loss, it became necessary to operate the soybean plant through idle periods of the corn plant, the wasted exhaust steam reached huge quantities.

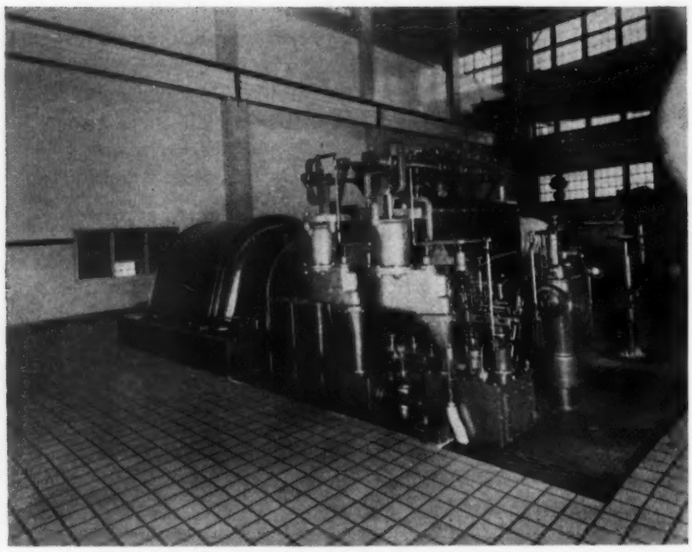
Latest Installation

Since the power had to be generated, the only answer was to produce it with less steam. A study which had been made in anticipation of this problem for the past ten years indicated the maximum economic efficiency could be secured with 400-lb steam at 700 F. The cost of equipment for such conditions is only slightly higher than that for the old 185-lb system, although still higher pressures would have been more expensive. This pressure is as high as practical without going into extensive and expensive additional equipment for feedwater treatment. Another factor governing the choice of pressure is the fact that the old 6000-kw turbine-generator had a 400-lb casing and with the installation of an additional 400-lb boiler could be converted to use this pressure at small expense.

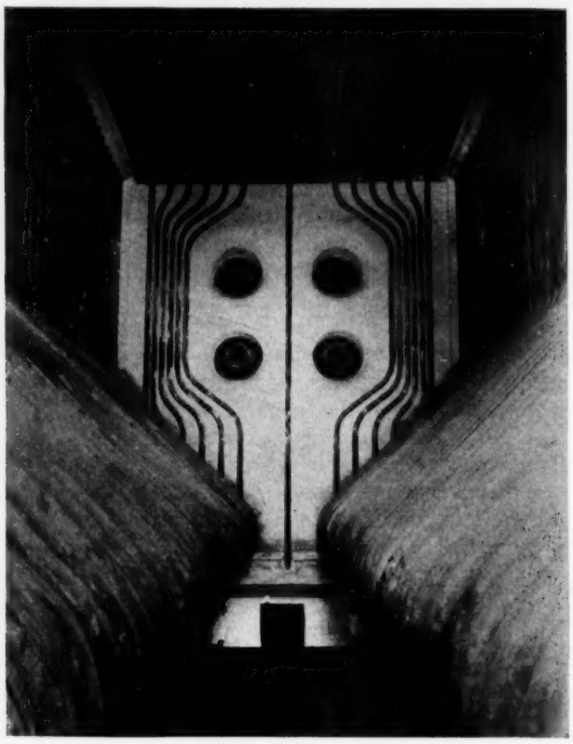


Layout of plant units with steam pressures indicated

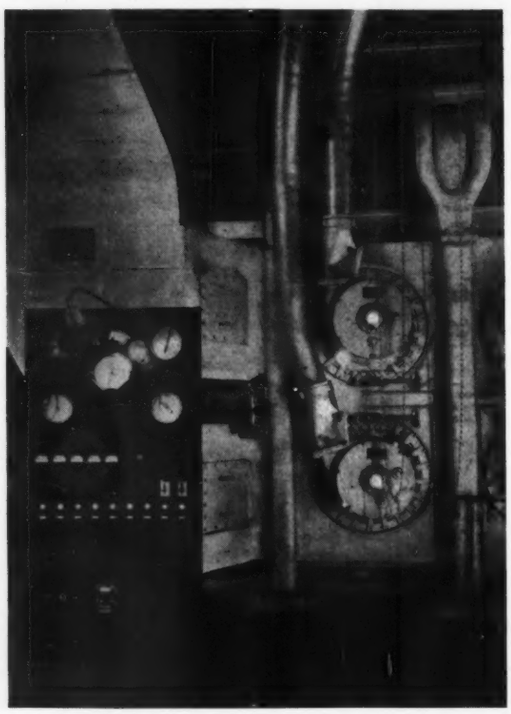
VIEWS OF LATEST ADDITION TO T



6000-kw extraction turbine-generator

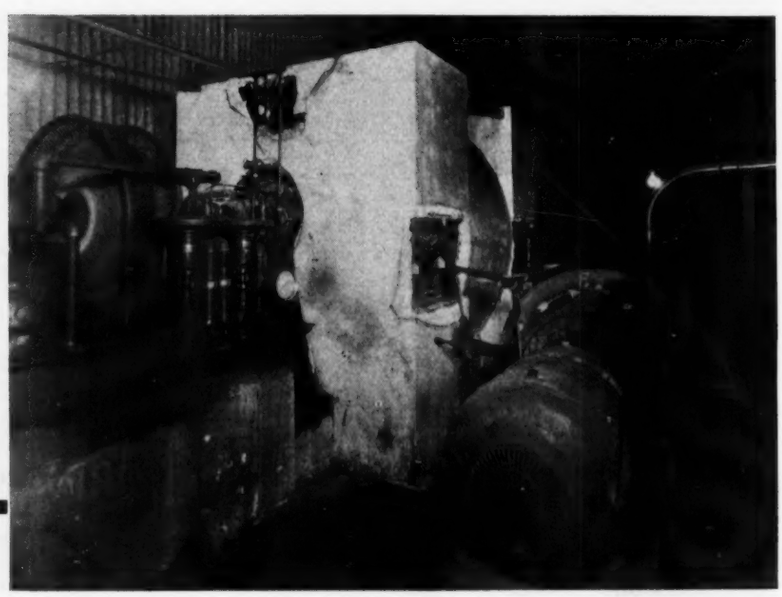


Looking through furnace toward burners



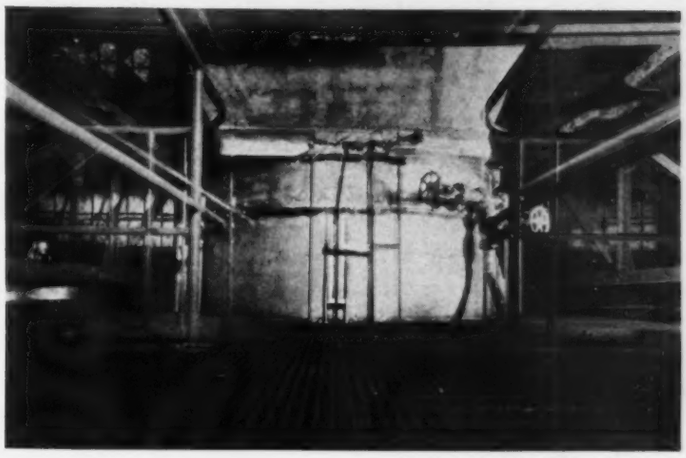
Looking toward front of west half of boiler, showing burners and panel containing starting buttons and ammeter for all motors, also gages showing feedwater pressure, drum pressure, water level, recording steam pressure and temperature gages

The forced- and induced-draft fans are located in a penthouse

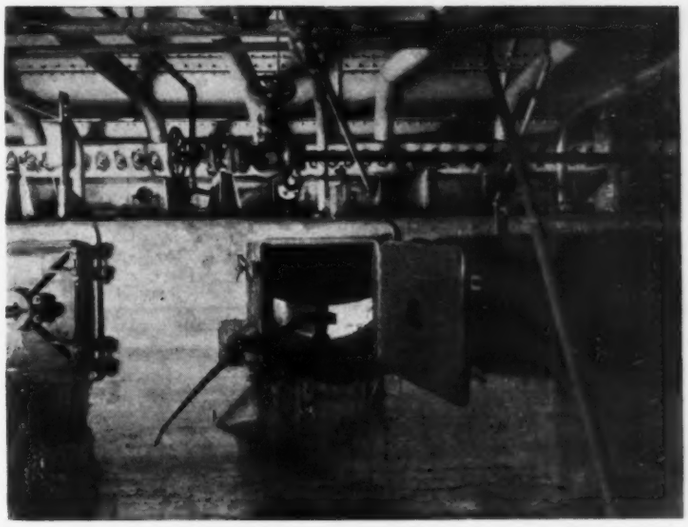


THE A. E. STALEY POWER PLANT

At right, Ljungstrom air preheater located over the boiler



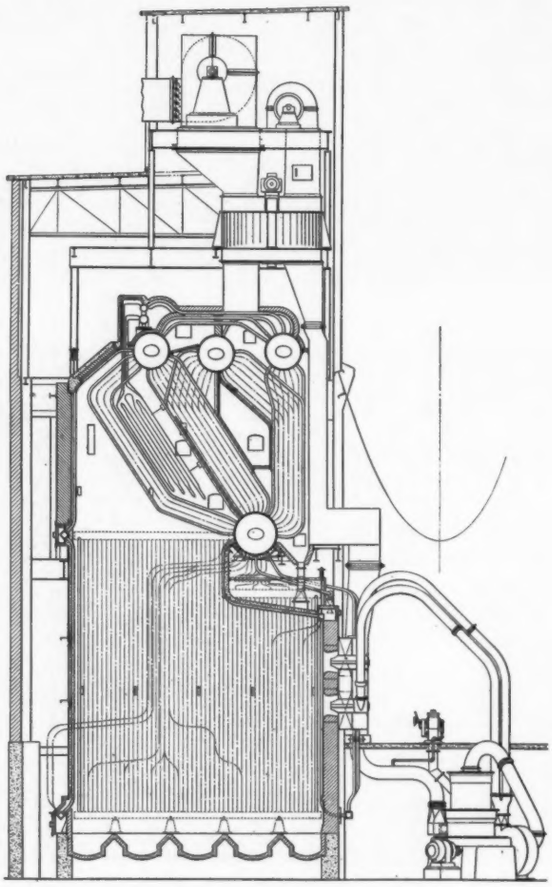
Interior view, No. 17 steam generating unit, from ashpit looking upward through V bottom and furnace to boiler



View of ash hopper under No. 17 unit

The boiler is served by these two 6-ton Raymond bowl mills located in the boiler-room basement

As a result of these conclusions, there was purchased and installed a C-E pulverized-fuel-fired bent-tube boiler of modern design, with fin-wall furnace construction, equipped with a superheater, an air preheater and all necessary auxiliaries. This boiler was specified to deliver 125,000 lb of steam per hour continuously or 150,000 lb maximum for four hours at a delivery pressure of 420 lb and a steam temperature of 700 F, and to have an overall efficiency of 83 per cent.



Section through new steam generating unit

To utilize the output of this steam generator, there was purchased a 6000-kw G. E. turbine-generator taking steam at this pressure and temperature and exhausting into the common exhaust main at 3 lb along with the old turbines. An additional feature of the new turbine was the provision of extraction facilities at an intermediate stage so that steam could be bled at 130 lb for use in process. Also, a special feature was added to the governor of this turbine. The capacity of this extraction stage was 100,000 lb per hr and with the boiler having only 125,000 lb per hr capacity the turbine could not carry full load unless more than 25,000 lb went completely through it. To prevent its laying down under a high extraction demand the governor was so built that it limits the extraction flow when the throttle pressure is reduced to 390 lb.

Under these circumstances the deficiency in the 130-lb line is supplied from the 185-lb system through a reducing valve. After additional steam generating capacity is added, of course, the full extraction capacity can be utilized even with full load. This turbine was also specified to be able to operate at 3200 kw under emergency conditions from the old 185-lb system and was so cross-connected and valved.

In order to utilize the steam generating capacity of the new boiler if the turbine were down, and also to utilize its full capacity when the turbine did not take it, a spill-over reducing valve and desuperheater were included in the plans. Whenever the throttle pressure at the turbine exceeds 405 lb and the low-pressure header is below 190 lb this valve opens, reducing the pressure to that of the low-pressure main. This steam passes through a desuperheater where a spray of boiler feedwater reduces its temperature from 700 to 450 F.

There are two controls on this valve, one on the high pressure and one on the low, and both function together to pass steam through the valve. That is, the low-pressure control must demand steam and then if surplus is available the high-pressure control permits it to pass. The actuating force on this valve is the boiler-feedwater pressure working on a diaphragm against a spring to open the valve. This is the water used in the desuperheater, so if there is a failure of water pressure to the desuperheater, the spring closes the valve, preventing the high-temperature steam from entering the low-pressure system. The low-pressure main is protected against high pressure by a relief valve set at 200 lb.

Space Limitations a Problem

As mentioned previously, the last addition to the boiler house had been built to accommodate six stoker-fired units, each of 55,000 lb per hr capacity, similar to Nos. 13 and 14. Two of these bays, Nos. 17 and 18, were available for the new unit and naturally it was decided to use No. 17 bay. Care was taken not to encroach into the aisle space, where it might interfere with adding a duplicate unit later in No. 18 bay. Many problems developed in planning a unit that would go into this space and still have almost three times the generating capacity, burn two and one-half times as much coal, and require much greater furnace volume in proportion to the quantity of coal burned than those originally planned for it.

Luckily, the boiler house as it is built has considerable unused height above the old boilers. For the new unit this space in bay No. 17 is all utilized. The three upper drums of the new four-drum boiler were carried on girders above the bunker floor level and the remaining space above was utilized for the air preheater. The fans were put in a penthouse on the roof. The greater part of the space between the firing aisle floor and the upper drums was thus available for the furnace of 9000 cu ft volume. From this furnace the ash falls into the hopper in the basement where the mills are also located.

The basement of this bay is almost completely filled with the ash hopper and the two bowl-type mills. These mills have a nominal capacity each of 12,000 lb per hr and are equipped with integral exhausters. Each mill and exhauster is driven by a 125-hp, 1200-rpm, totally enclosed fan-cooled motor.

The feeders, on the firing floor, are set so as not to be directly above the mill and the concrete floor directly over the mills has been taken out and a floor of removable grating substituted. Over this grating a trolley beam and trolley hoist have been installed to facilitate mill repairs. On the firing floor, at each side facing the aisle, are two instrument panels. The one at the left,

facing the boiler, carries the starter buttons and ammeters for all of the motors on the unit. From this point are started and stopped the two 125-hp mill motors, the 125-hp booster pump motor, the 125-hp forced-draft fan motor, the 175-hp induced-draft fan motor and the small motors driving coal feeders, air preheater and oil pump on the induced-draft fan hydraulic coupling. The indicating gages on this panel show drum pressure and feedwater pressure. Recording instruments register temperatures of coal, air mixture from the mills, temperature and pressure of steam in the header and water level in the drum. The panel on the other side carries the Bailey control equipment consisting of a master controller, mill-feeder control, exhauster-damper control, induced-draft and forced-draft controls. Also, on this panel is the steam flow-air flow meter which governs the fuel ratio, a pyrometer and a multi-draft gage.

Between the rear wall of the furnace and the building wall is installed a double compartment tank, one containing water and the other a solution of Hagan phosphate. By means of a timer controlling a pump and the suction valves, the metaphosphate solution is periodically injected into the mud drum and then the pump and lines are automatically flushed out with soft, clean water.

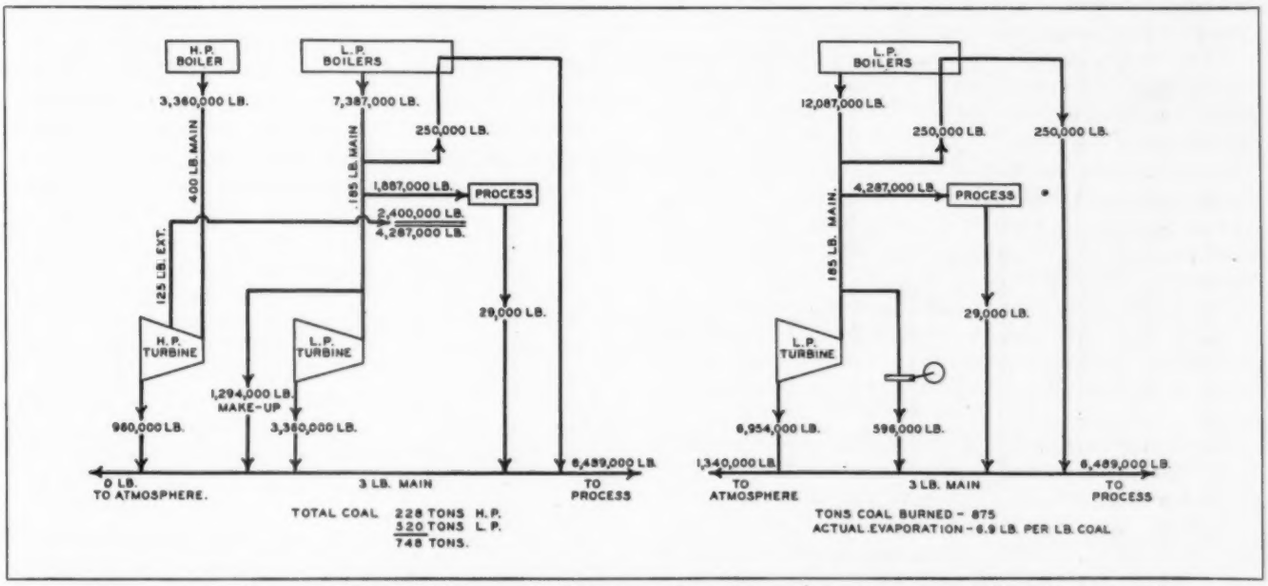
Continuous blowdown is used on all the boilers. The high temperature blowdown water is passed under pressure through a heat exchanger in the main feedwater line.

After passing through the exchanger the blowdown water is recovered by discharging it into the receiving chamber of the water purification plant. The normal feed to the boiler is by means of a motor-driven booster pump, set near the boiler. This pump takes its suction from the 275-lb line serving the other boilers and raises the pressure to 550 lb, delivering it into the front upper drum of No. 17 boiler through a Copes feedwater regulator which is mounted on the right side of the boiler at the drum level. Chain-wheel valves, with the chains within easy reach of the fireman, control the stop valve to the regulator and also an emergency connection, for hand regulation, into the left side of the same drum.

In case of failure of either the main feed pump or the booster pump an emergency turbine-driven feed pump starts automatically. This pump is located in the basement of the turbine house and takes its suction from the hot-water storage tanks below the deaerating feedwater heater. A failure in water pressure acts on a Copes trip valve which opens, starting the turbine and delivering water again to the boiler after only a few seconds interruption.

The water columns at each end of the middle upper drum are too high to be seen from the firing floor, hence are fitted with periscope attachments which reflect the water level to mirrors on the firing aisle where they are easily seen and indicated from the bicolor device on the gage glass.

While Nos. 15 and 16 boilers have plate-type heaters, a Ljungstrom regenerative preheater was selected for the latest installation. It was felt that this type would not be as susceptible to corrosion as the plate type and also that improvements had eliminated objectionable air leakage on this type. Space considerations also eliminated practically any other type.



Comparison of present (left) and former (right) steam flow diagrams under same load conditions with allowance for power required by high-pressure boiler auxiliaries

In order to conserve the space taken by resistance grids on slip-ring motors and also to simplify control, the forced-draft fan is equipped with inlet vane control, whereas the induced-draft fan is driven through a 30-inch hydraulic coupling.

The large motors are all of the 2300-volt, totally enclosed, fan-cooled, across-the-line start, squirrel-cage type. A 10-kw transformer reduces the voltage from the feeder supplying this unit to 440 volts for the small feeder motors, preheater drive, and hydraulic coupling oil-pump drive.

The furnace of the new steam generating unit is almost completely water cooled, with fin tubes on the arch, rear and side walls, including the V bottom. Below the water-cooled arch, the brick wall carrying the four burners is largely protected by bare tubes. In this furnace, as in that of unit No. 16, the V bottom runs longitudinally. However, in the case of No. 17 the side-wall tubes

are continuous through the V instead of being broken by a header as in No. 16. The fin walls are backed by tile, insulation and a tight steel casing. Above the fin walls the side walls are continued in brick, the outer layer of which is of the insulating type. The risers from the water walls run up along the inside of the brick wall. All precautions were taken during erection to seal all joints and protect against air infiltrations. Orstat determinations indicate that these precautions were successful as only $^3/_4$ per cent drop in CO_2 was found between the furnace and the preheater outlet.

Erection was started early in 1937 and by April of that year the turbine-generator, with the necessary switchboard additions, was completed, and put into operation on 185-lb pressure. This relieved the overloaded condition of the turbine plant and effected a considerable saving because it could be loaded up to 3200 kw at a steam rate of 28-lb per kwhr, as compared with the 38-lb rate for the two small old machines. The boiler and piping were finished in November and put into service immediately, with no trouble. The combination has been in practically continuous operation ever since.

When the new boiler was started six old boilers were taken out of service completely and two to six of the remainder are out part of the time, depending on the load and season of the year.

In addition to the saving made through the reduced steam consumption of the 400-lb turbine there is a large coal saving due to generating steam from the new unit at 83 per cent efficiency compared with the 65 per cent efficiency of the discontinued boilers.

The steam extracted at 130 lb generates enough power to bring the rate for the steam passing completely through the turbine to the 3-lb exhaust main to only 13 lb of exhaust steam delivered per kilowatt-hour generated.

During the remainder of the winter, power peaks of 11,000 kw were carried and as high as 222,000 kwhr generated in 24 hr with 210,000 to 214,000 kwhr normal for a day's operation with full grind on both the corn and bean plant. Under these conditions, instead of wasting 1,000,000 lb of exhaust per day, as would have been done with the old system, it was necessary to use 1,000,000 to 2,000,000 lb of live steam makeup to the exhaust system. Through the past summer, although the summer exhaust demand is about 1,000,000 lb per day less than winter, the plant ran on an almost perfect heat balance under normal load. A large saving was made during the dull corn grind season, when it was necessary to run the beam plant while the corn plant was down. At these times the demand for 3-lb steam is almost negligible. Formerly, with the old machines running non-extraction and a high steam rate, the waste was tremendous. With the process steam to this department served from the extraction and the low steam rate for generation, the exhaust waste became small.

Operating Results

The following tabulation may be of interest showing operation of the new system for the 24 hr of February 17 last.

Boiler output average rate 137,000 lb per hr	3,296,000 kwhr
Power generated by new turbine, 5,500 kw average load	131,000 kwhr
Steam to turbine	2,950,000 lb
Extracted at 130 lb pressure to process	1,252,000 lb
Passed through turbine to exhaust system	1,698,000 lb
Passed through reducing valve and desuperheater	346,000 lb
Steam discharged to exhaust per kwhr	12.8 lb

When this 12.8-lb exhaust rate is compared with 28 lb for the old 6000-kw turbine and 38 lb for the 2500 and 1500-kw machines, it is easy to see why the coal consumption has been greatly reduced and operations simplified by running one boiler instead of eight or ten, and two turbines with a large margin of reserve instead of three, overloaded.

Records kept on boiler performance indicate that the operation has conformed to the specified performance conditions which were as follows when burning Central Illinois screenings. The coal burned approximates the following specifications:

Btu as fired	9800
Prox. analysis (as fired)	
Fixed carbon	39 per cent
Volatile	32 per cent
Ash	16 per cent
Moisture	13 per cent
Sulphur (separate determination)	4.5–6 per cent
BOILER PERFORMANCE	
Evaporation, lb per hr	125,000
Fuel, as above	
Pounds of coal per hour	17,680
CO_2 in flue gas	14.5 per cent
Temperatures of:	
Gas entering heater	750 F
Air entering heater	80 F
Air leaving heater	575 F
Gas leaving heater	416 F
Pressure, lb per sq in. at superheater outlet	420 ga.
Feedwater temperature	230 F
Total steam temperature	700 F
Combined efficiency	83.2 per cent

During the period from January 1, 1938 to September 15, 1938 this boiler has been on the line 90 per cent of the total elapsed time, and was available for at least 95 per cent of the period. During this period it has burned 44,368 tons of coal and generated 621,499,000 lb of steam. This is an average of 112,000 lb per hr and when it is understood that during many weekends this unit carried the entire plant load at reduced rating it is obvious that a high continuous rating has been maintained 24 hr per day, most of the time.

One of the largest factors contributing to the satisfactory operation of this unit are the Raymond bowl mills. These were selected as a result of experience with several types of mills and a thorough investigation of a number of others.

Late in 1935 the decision was made to use bowl mills for the proposed unit and it was realized that it would be over a year before the plans could be completed and the unit installed and put into operation. It was felt that the operation of the old steam generator, No. 15, could be improved and valuable information secured on these bowl mills if one were substituted for an impact mill on this unit. In January 1936 a bowl mill identical with those selected for No. 17 was installed on No. 15 boiler and immediately put into operation with highly satisfactory results. Records on this mill and the two installed on No. 17 show that the mill maintenance cost has been reduced from about 14 cents to less than 6 cents per ton of coal ground. These figures cover labor as well as material and, while they may seem high to users of low-ash, low-moisture, or low-sulphur coal, they are very satisfactory with the coal used. The moisture on these local screenings usually runs about 13 per cent, and a very slight addition of surface moisture will reduce the capacity of a mill considerably. All primary air is taken directly through the mill at full temperature without tempering, as it is needed for drying purposes in the mill. The high ash, with a very high pyrites content, is extremely abrasive. On the old impact mills 600 to 900 tons of coal per set of hammers was about as much as could be expected. The difference between the wear with this

coal and coal only slightly better can be realized when it is stated that with Southern Illinois coal double the above hammer life is obtained. However, the increased freight rate eliminates this desirable fuel from consideration. The bowl mills run comparatively long periods without having to be opened for repairs. At first the sweeps were the most vulnerable portion as they wore out rapidly. However, this has been overcome by stelliting the surface and lately a coating of tungsten carbide seems to be offering much promise.

An interesting feature of these mills is the quantity of pyrites discharged from the tramp iron spout. These particles of pyrites, varying from the size of a pin head to particles as big as a hazelnut, throw over the edge of the bowl and discharge from the tramp iron spout. Sweeping these along continually is what wears the sweeps. As much as 3000 lb of pyrites per day are rejected from each of the three bowl mills in service.

To continue the comparison with impact mills, the power consumption has been reduced appreciably and the mills are able to run up to six or seven thousand tons before it is necessary to open them for inspection. At about this period it is necessary to renew exhauster blades and certain exhauster and mill liners. The rolls and rings ordinarily last until nearly 20,000 tons have been ground.

Another desirable feature of these mills is that fineness and capacity are well maintained throughout the life of the wearing parts.

Annual Coal Savings 40,000 Tons

The savings accomplished by the installation of this boiler and turbine are hard to evaluate precisely as operating conditions have changed considerably since the survey and original comparisons were made. But it seems conservative, from an investigation of past and present records, to calculate that for 250 complete operating days in the year, 150 tons of coal are saved each day, and that for 80 more days about 50 tons per day are saved, making a total coal saving for the year of approximately 40,000 tons. Of course, much of this is due to the application of steam in the generation of power due to the higher pressure and temperature, but a very large part of it is also due to a large increase in the efficiency in the boiler house itself, due to the new boiler unit.

In addition to direct coal savings, a considerable labor saving was made due to simplification of operations as, in using less boilers and more automatic equipment, the boiler house personnel was reduced by six men in each 24-hr shift.

Also the percentage of makeup boiler feed has been reduced due to the elimination of steam blowing to waste. The total maintenance per ton on the new unit is considerably less than the total maintenance on the eight small boilers it displaces. The repairs on the water-cooled furnaces are very slight as compared with repairs on the refractory lined furnaces of the smaller units.

When all of these factors are taken into consideration, it is easy to see that the savings pay a big return on the investment.

While now there is considerable reserve capable of absorbing additional load, there still remain future possibilities for increased demand. No. 18 bay is left in the boiler house and can be filled with another similar boiler. By converting the 185-lb., 6000-kw turbine-generator and lowering its steam rate to 18 lb per kwhr from 28 lb more power can be generated, with less exhaust steam, and the surplus steam from an additional boiler can be utilized by the extraction from the new turbine.

Principal Equipment—A. E. Staley Mfg. Co., Decatur, Ill.

Steam Generating Equipment	
BOILER, four-drum, bent-tube type, 125,000 lb/hr at 425 lb design pressure, 700 F	*Combustion Engineering Co.*
SUPERHEATER, Elesco convection type	*Superheater Company*
FURNACE, 9000 cu ft, waterwalls with plain and C-E fin tubes	*Combustion Engineering Co.*
SOOT BLOWERS	*Vulcan Soot Blower Corp.*
SAFETY VALVES, 2 per boiler, 1 on superheater	*Crosby Steam Gage & Valve Co.*
FEEDWATER CONTROL, Copes	*Northern Equipment Co.*
WATER COLUMN, 2 Diamond with 12-in. vision bi-color illuminators	*Diamond Power Specialty Corp.*
COMBUSTION CONTROL	*Bailey Meter Co.*
BLOW-OFF VALVES	*Edward Valve & Mfg. Co.*
Pulverized Coal Equipment	
PULVERIZERS, 2 Raymond bowl mills, 6-ton capacity, integral exhauster	*Combustion Engineering Co.*
PULVERIZER DRIVE, direct-connected, 125-hp, 1200-rpm, 2300-v, 3-ph.—60, cy., totally enclosed, fan-cooled motors	*Allis-Chalmers Mfg. Co.*
COAL FEEDERS, star type with variable speed through "Sterling Speedtrol"	*Combustion Engineering Co.*
COAL BURNERS, four Type R	*Combustion Engineering Co.*
Draft Equipment	
INDUCED-DRAFT FAN, one 99,300-dfm at 6.6-in. w.g. and 418 F	*Clarage Fan Co.*
I. D. FAN DRIVE, 30-in. hydraulic coupling	*American Blower Corp.*
I. D. FAN MOTOR, 175-hp, 2300-v, 3-ph., 60 cy., 870 rpm	*General Electric Co.*
FORCED-DRAFT FAN, one 53,700-cfm at 9.6-in. w.g. and 100 F, with inlet-vane control	*Clarage Fan Co.*
F. D. FAN DRIVE, direct-connected 125-hp, 1750-rpm, 2300-v, 3 ph., 60-cy. totally-enclosed, fan-cooled	*Allis-Chalmers Mfg. Co.*
AIR HEATER, Ljungstrom, 12,900 sq ft	*Air Preheater Corporation*
Boiler Feedwater System	
FEEDWATER HEATER, Elliott open-type deaerating	*Elliott Company*
BOILER FEED PUMP, one 400-gpm at 1305 ft head	*Ingersoll-Rand Co.*
ELLIOTT TURBINE	*Elliott Company*
BOILER FEEDWATER BOOSTER PUMP, one 400-gpm at 668-ft head	*Ingersoll-Rand Co.*
DRIVEN BY 100-HP, 1750-rpm, 2300-v, 3-ph., 60-cy., totally-enclosed, fan-cooled motor	*Allis-Chalmers Mfg. Co.*
Ash Removal Sytem	
ALLEN-SHERMAN-HOFF HYDRO-JET SYSTEM	*Allen-Sherman-Hoff Co.*
Electric Equipment	
CONTROL PANEL, magnetic contactors with complete interlocking system by	*Electric Controller & Mfg. Co.*
Meters and Instruments	
DRAFT GAGES	*Hays Corporation*
AIR- AND GAS-TEMPERATURE RECORDERS	*Brown Instrument Co.*
INDICATING AND RECORDING PRESSURE GAGES	*Foxboro Co.*
RECORDING THERMOMETERS	*Foxboro Co.*
WATER-LEVEL RECORDER	*Republic Flow Meters Co.*
STEAM AND WATER FLOW-METERS	*Republic Flow Meters Co.*
Piping	
CONTRACTOR	*Power Piping Co.*
INSULATION	*Prillaman, Inc.*
VALVES	*Edward Valve & Mfg. Co.*
Desuperheater and Reducing Valve	
CARBURETOR-TYPE DESUPERHEATER with pressure-reducing and pilot control valves, 15,000 lb of steam per hr	*The Swartwout Co.*
General Equipment	
TURBINE, 6000-kw, 11-stage, non-condensing, throttle press 400 lb at 3 lb ga. back pressure with 125 lb ga. extraction	*General Electric Co.*
GENERATOR, 6000-kw, 2300 v, 3 ph., 60 cy., 3600 rpm, with direct connected exciter	*General Electric Co.*
BUS STRUCTURE, oil circuit-breakers, control panels	*General Electric Co.*

Considerations Affecting Selection of Pulverizers

By S. H. REID
Combustion Engineering Company, Inc.

The effect of coal characteristics and required fineness on mill capacity is discussed, as well as drying and tempering in the mill. Recommended fineness for high- and low-volatile coals is given and the influence of operating conditions on the number of mills selected is considered.

MAJOR considerations in the selection of milling equipment for a steam generating unit are that it shall be able to carry the load and be suitable for pulverizing the particular coals to be burned. The steam output, heating value of the coal and the overall efficiency of the unit determine the actual pulverizing capacity required, whereas the number of mills is governed by the anticipated load, the operating conditions and the individual mill capacities available.

Manufacturers of pulverizing equipment have chosen to rate their mills as to capacity when grinding Pittsburgh No. 8 coal, containing 5 per cent moisture, to such fineness that 65 per cent will pass through a 200-mesh screen. This may be termed the "nominal capacity." However, as will be shown later, the actual capacity varies and depends upon several factors, including the fineness required, the grindability of the coal and its moisture.

The fineness to which a coal should be pulverized in order to insure satisfactory combustion is influenced by its volatile content which, in turn, affects the time

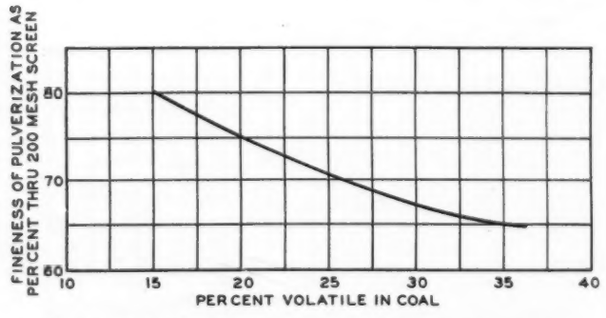


Fig. 1—Relationship between volatile and fineness

allowed for combustion in the furnace. This governs the length of flame travel, the furnace proportions and the type of burner. The higher the volatile content the easier it is to ignite and burn the coal completely. With a high-volatile coal there is less fixed carbon left in the coal particle, hence the time required to burn it completely is less than where the volatile is low.

The curve in Fig. 1 shows a satisfactory relationship between volatile content and coal fineness. It will be noted that the lower the volatile, the higher the percentage that should pass through a 200-mesh screen. However, medium- and low-volatile bituminous coals are generally easier to grind than high-volatile coals.

Unburned carbon is seldom found in the remains of particles passing through a 200-mesh screen but rather

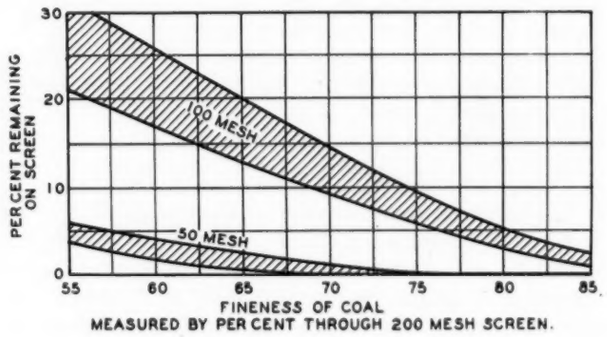


Fig. 2—Results of screen tests

in those that do not pass a 100- or 50-mesh screen. Therefore, it is important that the latter be kept to a minimum. It is these large particles that show up in the furnace as "sparklers" and tend to intensify slagging. A satisfactory fineness for a high-volatile coal is 65 per cent through a 200-mesh, 85 per cent through a 100-mesh and 98 per cent through a 50-mesh screen. A low volatile coal may require 80 per cent through a 200-mesh, 95 per cent through a 100-mesh and over 99 per cent through a 50-mesh screen. The large percentage through a 200 mesh assists in maintaining stable combustion. Fig. 2 shows the results of screen tests on coal samples which gives an idea of the gradation in particle sizes for various percentages through a 200 mesh.

Mill Capacity vs. Fineness

As previously stated, the capacity of a mill varies with the fineness of grinding. The coal usually travels in a circuit from the grinding chamber to the separator, or classifier, and back to the grinding elements until it is of such fineness that it will pass through the classifier into the transport pipe. Fig. 3 shows the general relationship of fineness to full load capacity for one type of mill in which normal capacity is based on the quantity that can be ground to 65 per cent through 200 mesh.

Coals vary widely in grindability. The curve of Fig. 4 is typical of the relationship between grindability and mill capacity, with a given moisture and fineness. This is based on the A.S.T.M. tentative standard (D-409-37-T) as to grindability, commonly known as the Hardgrove scale. Grindability tests, as usually run, give fairly true indications of how a coal will act in a mill. However, where a mixture of two coals of different grindabilities is being tested, the more friable portion will be reduced so it will pass through the finer screen while the harder will scarcely be touched. Thus the indicated grindability will be too high. Therefore, care and judgment must be exercised in interpreting such grindability data.

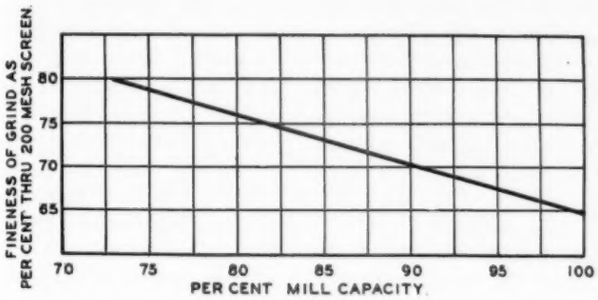


Fig. 3—Relation of fineness to mill capacity for one type of mill

Both maintenance and power consumption are functions of the grindability of the coal. With some mills both low maintenance and low power consumption are attainable with certain coals, whereas some other types of mills, that are especially adapted to handling anthracite and other highly abrasive coals with minimum maintenance, will run to high power consumption. In some such cases it may prove more economical to sacrifice power consumption for the sake of lower maintenance, but with most bituminous coals that are being burned in pulverized form in this country it is usually more economical to conserve power consumption and tolerate a moderate amount of maintenance.

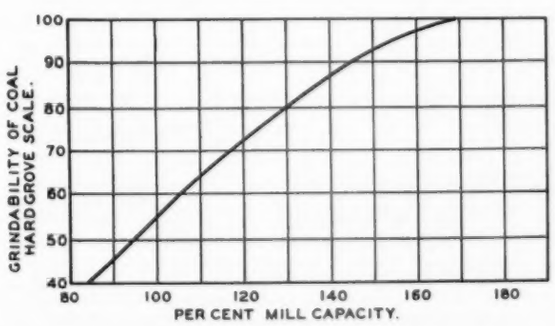


Fig. 4—Relation between capacity and grindability, referred to the Hardgrove scale

Present practice is to dry coal in the mill, in contrast with the earlier practice of employing separate coal driers. The capacity for drying coal in the mill is dependent upon the amount of heat that can be provided. This, in turn, depends upon the quantity and temperature of the air or gas that can be supplied for this purpose. The air is usually tapped from the hot air duct when the boiler is provided with an air preheater; or, in the absence of such an air preheater, it may be heated by means of a separate steam-air heater. The latter practice, however, is less common. In the first case the temperature is limited to that produced by the preheater and in the second by the steam temperature which with low-pressure steam may be inadequate.

The quantity of air available is limited by the exhauster fan characteristics, selected to meet the general mill, burner and piping requirements. Where the preheat temperatures are limited or the coal is unusually wet, it may be desirable to provide an oversize exhauster fan to care for drying the coal. This has some disadvantages in direct-fired systems, particularly as it limits wide ranges in load, because the excess of primary air handled at low ratings makes a very lean mixture that results in an unstable flame. In order to handle the large volume of air satisfactorily the transport pipe and burner throat must also be oversize. As the amount of primary air is cut down to give a richer mixture at lighter loads the velocity may fall to the point where the flame will work back into the burner or coal may lodge in the system due to low velocities. However, if the load range is not too wide this is a satisfactory way of handling the problem.

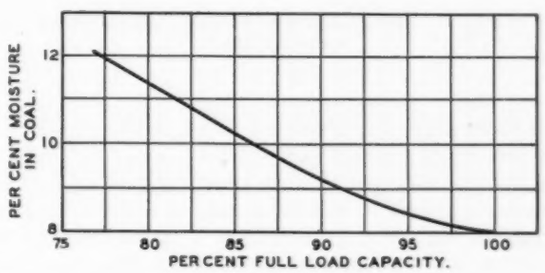


Fig. 5—Moisture content vs. capacity for Pittsburgh coal and roller mill

In some instances, with direct-fired systems, hot gas has been drawn from the furnace or setting and mixed with air to dry the coal in the mill. This practice has two disadvantages; first, the primary air is diluted with CO_2 and nitrogen, thus making stable ignition more difficult; and secondly, there is the possibility of drawing sparks into the mill. The National Board of Fire Underwriters has ruled against this practice unless the gas be drawn from the setting after it has traversed a certain portion of the boiler surface. This requires more gas to accomplish the drying and aggravates the problem of maintaining stable ignition and complete combustion. In a storage system it is preferable to employ gas for drying and transport because of the reduced chances of fire or explosion.

Where the unit is provided with an air preheater it is better, from the standpoint of overall efficiency, to draw as much as possible of the drying air through the preheater. However, the temperature of this air may be too high to be used directly with safety, in which case, depending upon the moisure in the coal, it may be necessary to temper it with cold air from the boiler room. Experience has shown that 175 to 200 F is usually satis-

factory for the mill exit temperature with eastern coals and about 150 F for midwestern coals for direct fired systems. Coals that are subject to spontaneous combustion in storage usually require lower temperatures. With low moisture coals such tempering with cold air is generally required and this reduces the amount of air that can be drawn from the preheater.

Despite drying, a mill is unable to handle as much wet coal as dry coal. Trouble may be encountered in the spouts to the feeder, in the feeder and in the pipe from the feeder to the mill. The introduction of heated air

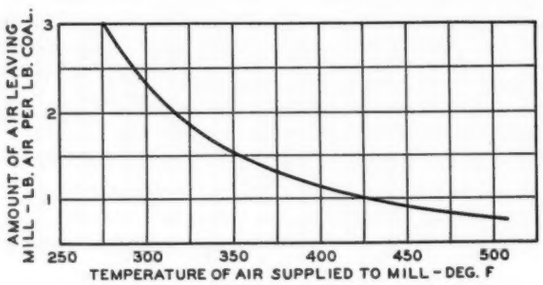


Fig. 6—Temperature of primary air required at mill inlet

into these parts has corrected much of this trouble. In the process of milling, the wet coal must remain in the mill system a longer time in order to give up sufficient moisture so that it can be pulverized and transported satisfactorily. Fig. 5 shows the relation between mill capacity and moisture content of the coal, based on a typical Pittsburgh coal for a roller type mill. A somewhat similar relation will hold for other coals and mills.

The amount of moisture which a coal can retain and still be handled satisfactorily depends upon its characteristic, termed inherent moisture. In general, midwestern and western coals can be pulverized as readily as those from the Pittsburgh seam even though containing approximately 5 per cent more moisture. Fig. 6 shows the temperature of primary air required at the mill inlet to dry a coal with varying ratios of primary air to coal.

Direct Firing and Bin System Compared

When pulverized coal was first introduced it was usually handled in what is known as a bin system. This system has certain advantages but it is higher in first cost than a direct-fired system. Whether the greater investment may be justified depends on several factors. The advantages of a bin system are that absolute control over coal feed is had; the ratio of primary air to coal can be varied widely to give most satisfactory combustion; load range can be practically anything and the burners can be cut in and out at will. If it is necessary to provide for a very wide load range and keep a unit in continuous service for extended periods this system is the most advantageous. The mill capacity can be divided between a few large units and they can be operated at their full rating and then shut down. This is economical from a power consumption standpoint and also provides against loss of service should a mill be down for maintenance or adjustment. Usually, no tempering air need be provided for the mills, which, in turn, gives better air preheater performance.

In most cases, however, the added expense for a bin system cannot be justified and satisfactory operation can be had by firing directly to the boiler. It is easier to operate a mill having direct-connected burners at near its rated capacity; but at very low loads, while the mill functions without difficulty, the fire may become unstable in the furnace. This is because it is usually impossible to reduce the air flow through a mill to the same extent as the coal feed is reduced and thereby maintain the desired ratio of primary air to coal. If the air flow were so reduced trouble probably would be experienced with coal drifting, uneven supply of coal and pulsating flame.

Because of the lean mixture it is not so satisfactory to provide a mill with several connected burners and to cut out burners at low loads. The velocity through the burner in operation then becomes too high and the mixture too lean to give satisfactorily stable operation.

Except for small capacity units it is better to employ at least two mills to give load range and provide for operation at reduced loads with one mill out of service. This arrangement has the added advantage of preventing boiler shutdowns should the feeder on one mill become plugged or some such other minor disturbance interrupt mill service.

Quite frequently mills are specified to have such capacity that full load or a large fraction of full load can be carried with one mill out of service. This is advantageous in many cases but in others the disadvantage of not being able to carry low loads satisfactorily outweighs the advantages gained. A mill and burner can operate easily over a range of 3 or 4 to 1. With good burner design and a coal that burns readily this range can be spread considerably but the greater the range the more difficult the operation becomes. Load ranges of 10 or 12 to 1 and higher can be reached but they usually are more of the nature of stunts than practical operation. This fact should be kept in mind when considering the increase in mill size to provide reserve capacity.

Power consumption by a mill is always less per ton of coal ground at its full capacity than at partial loads. Fig. 7 shows how the power per ton of coal will in-

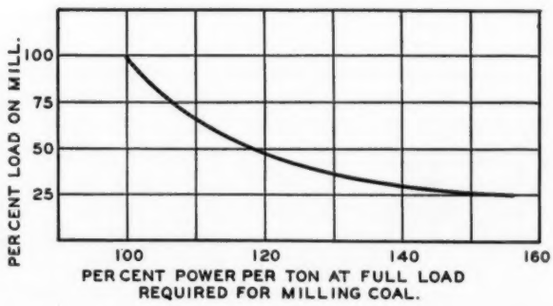


Fig. 7—Power required per ton of coal plotted against mill loading

crease with decrease in load on one type of mill. This fact also has a bearing on the selection of mill size.

The considerations affecting the selection of a satisfactory pulverizing system may be summarized as follows:

It must be able to handle sufficient coal and grind it to the proper fineness. It must be reliable and flexible enough to meet the load range. It must be economical in power consumption and maintenance.

LUBRICATION of Power Plant Auxiliaries

By A. F. BREWER
Technical Division,
The Texas Company

The importance of proper lubrication of auxiliaries as insurance against outage, excessive maintenance and undue power consumption is stressed and suggestions are made as to lubricants best suited for various component parts of pumps, stokers, pulverizers, fans, motors, etc.; also their drives. Because of variations in types and designs of such auxiliaries, general, rather than specific, recommendations are made.

THE steam plant auxiliary has become a most important adjunct to the steam generating unit and the prime mover in the modern power plant in maintaining the required reliability and designed economy of the plant as a whole. Failure of an auxiliary may result in serious outage and costly loss in production. To this end careful consideration is warranted in the selection and operation of such auxiliaries as pumps for various services, stokers, pulverizers, feeders, fans, motors, etc., and especially their drives. The lubrication of such equipment is most important from the standpoints of dependability, minimum wear and power consumption. Only oils and greases of proven performance and adaptability to the particular service should be employed.

No longer is the power engineer content to accept that certain amount of waste which once characterized lubrication. This is why the designing engineer has utilized means for oil circulation wherever practical and improved upon the types of gear housings so necessary in certain drives.

As a rule, it is possible to employ on auxiliaries most of the lubricants used on the main units. For instance, electric motor bearings can be served either by light turbine or engine oils; external pump and stoker-engine lubrication can be effected with engine oil and the steam cylinders of the latter can be satisfactorily lubricated with the same grade of cylinder oil that is recommended for the main engine.

In some cases, of course, conditions may vary. Certain motors may be located in enclosed housings or be subject to such high temperatures that a light 180 viscosity turbine oil would not be suitable; or the steam used in a reciprocating pump may be of different temperature from that employed in the main unit. However, such variations can readily be met by cooperation with the lubricating engineer of a reputable oil company and two or three additional grades of lubricants substituted for these services at approximately the same cost.

Auxiliaries should not be lubricated by cheap oils or greases, for they usually receive less attention than the main units because of their customary location in galleries, pits or less accessible places. Moreover, they are often arranged for remote or automatic starting and stopping and are not under the constant supervision of an operator as are the main units, where any indication of faulty lubrication will be promptly noted and checked.

Pump Lubrication

In this category may be considered the reciprocating steam pump, the turbine- or motor-driven centrifugal and rotary or triplex pumps; their lubrication can be classified as follows:

a. Steam-cylinder lubrication
b. Lubrication of external parts
c. Bearing lubrication

Steam-cylinder lubrication should be studied with respect to the steam conditions and their effect on the lubricant. In some plants all reciprocating units operate under the same steam pressure and temperature whereas others may employ superheated steam for the main units and saturated steam for the pumps. In the latter case, the same cylinder lubricant will not be adaptable to both and some variation in compounding and refinement of the oil will be advisable. The exact nature of the oil to be used will depend upon the steam temperature, quality and pressure, also the type of lubricators employed. With pumps that operate on saturated steam the choice of a suitable oil is not subject to as wide a variation and one can usually select a medium or highly compounded oil, according to the percentage of moisture in the steam.

Lubrication of the external parts of a reciprocating pump does not involve any problem and usually the same oil can be used as that recommended for the same type of service on the main engine. However, if the prime mover be a steam turbine, it would not be economical to use a high-grade turbine oil for the pump—an engine oil will serve the purpose. While this would involve stocking an additional lubricant, the saving in first cost will more than offset any extra cost of handling and storage.

Bearing lubrication, as pertains to electric motors, centrifugal and rotary pumps, will normally present no difficulties. Whether they be oiled by hand, waste pad oilers, sight-feed cups or automatically, they will in most cases require the same grade of engine oil as that used for the bearings of reciprocating engines.

Where the equipment has been designed for grease lubrication of certain members, compression grease cups or pressure gun fittings will be employed. Grease lubrication has decided advantages in many cases whereas in others it is quite inefficient and conducive to trouble.

Stokers

Mechanical stokers may be driven direct by steam pistons, or where driven by motors, turbines or steam engines some form of variable-speed transmission or hydraulic (oil) drive is employed. This is necessary because the stoker operates at a speed very much lower than that of the motor, turbine or engine. Whichever type of drive is used, one has to deal with the problem of relatively high surrounding temperatures and the presence of ash or coal dust which in contact with moving surfaces tend to act as abrasives and accelerate wear. For this reason enclosed gear cases are usually employed where possible, particularly for worm drives and careful, as well as regular, attention to lubrication becomes necessary.

The direct-acting steam cylinders and steam engines are lubricated by a heavy refined cylinder oil, and regular engine oil or cup grease is most adaptable to external lubrication such as guides, pins, etc. Motor bearings will call for a light turbine or engine oil and, of course, a suitable turbine oil, similar to that recommended for the main unit, will be used for the steam turbine, if such drive is used.

The kind of gear lubricant will be dictated by the type of drive. With a worm drive, employing an enclosed case system, a medium to fairly heavy steam cylinder oil will be used, depending upon the season. This should be sufficiently adhesive to stick tenaciously to the teeth, resist the wiping action of the worm, and still be fluid enough to lubricate the thrust- and worm-shaft bearings. For normal operation an oil having a viscosity of around 150 sec Saybolt Universal at 210 F will prove most satisfactory. For high temperatures, a somewhat heavier oil should be used. It is usually well to flush the case and renew the oil every three or four months although longer periods may be found to suffice. With an open gear case, however, a considerably heavier lubricant should be used and applied directly to the teeth with a brush or swab. This should be as adhesive as possible to resist the action of centrifugal force and the wiping effect of the teeth.

Shaft bearings are usually of the split or solid babbitted type, equipped for hand oiling or provided with oil or grease cups. In cases where ball or roller bearings are employed they will require a machine oil or special antifriction bearing grease, according to the means available for application. A medium grease is used on rocker bars.

Where chain drives are installed a medium-bodied pure mineral gear oil or light grease will be adaptable, depending upon the design of the chain.

Pulverizers

The lubrication of equipment for pulverizing coal depends to a large extent upon the type and design of mill. In general, for ball thrust bearings and worm-gear drive a high grade compounded cylinder oil will prove satisfactory. This must be non-foaming if it is to be circulated through the oiling system, and the oil should be changed whenever it shows signs of contamination or a tendency to thin out. Roller journals and vertical shaft bearings will take an engine oil. An all-purpose oil will suffice for sleeve bearings, but grease is sometimes used. Rocker arms require a medium grease and special fittings are often provided for the application of grease guns. Mill-fan bearings will require a relatively light engine oil.

In all cases before removing an oil plug it is well to wipe off carefully all dust in order to prevent any foreign matter getting into the oil well.

Electric Motors and Fans

Lubrication of motors is confined entirely to their bearings. These are individually lubricated. The antifriction type is usually lubricated with grease. When sleeve bearings are involved, however, they may be built with some form of self-contained oiling system such as ring oilers or wick feed. The former are used chiefly on larger motors, wick feed being confined to smaller units. For motor lubrication a relatively light, straight mineral engine oil or a special ball or roller bearing grease should be employed. It must not separate, oxidize or develop gummy deposits which would hinder free movement of the rolling elements.

As in the case of motors, the lubrication of fans for forced and induced draft, ventilation and other services applies to their bearings and the same considerations govern. As to their drives, what has been said with reference to motors, turbines and engines will also apply.

Although scrapers are seldom, if ever, provided with modern economizers, there are, nevertheless, many such installations still in service and it may be in order to consider briefly the lubrication of their scraper driving mechanisms, such as motors, reversing devices, gears, chains and miscellaneous bearings. Motor lubrication has already been discussed. On the gears, chains and reversing mechanism it is necessary to insure the frequent and proper application of a lubricant that will not be conducive to dripping or be thrown off by centrifugal force in the event of abnormal rises in the housing temperature. For this purpose a good adhesive gear compound is applicable.

The following chart will serve as a summary of what has been covered and as a guide in selecting the proper lubricants for various power plant auxiliaries. Because of the variety of designs and types of equipment involved, it is necessarily quite general and may not apply to specific cases which should follow recommendations of the equipment manufacturer or the lubrication engineer.

LUBRICATION CHART

PRIME MOVERS	
STEAM ENGINES	
Cylinders	Cylinder oil
External lubrication	Engine oil or grease
STEAM TURBINES	
Bearings	Turbine oil
Thrust bearings	Turbine oil
Reduction gears	Turbine oil
HYDRAULIC TURBINES	
Thrust and step bearings	Turbine oil
Guide bearings	Turbine oil
Gate mechanisms	Water-resistant grease
DIESEL ENGINES	
Cylinders	Diesel engine oil
Bearings	Diesel engine oil
Valve mechanisms	High-melting-point grease

(Continued)

AUXILIARIES .	
PUMPS—RECIPROCATING, ROTARY	
Steam cylinders	Cylinder oil
Bearings	Engine oil or grease
External lubrication	Engine oil or grease
STOKERS	
DIRECT DRIVE—STEAM CYLINDERS	Cylinder oil
STEAM ENGINE DRIVE	
Engine cylinders	Cylinder oil
Engine guides, bearings, etc.	Engine oil
MOTOR DRIVE	
Bearings	Light turbine or engine oil
TURBINE DRIVE	
Bearings	Turbine oil
GEARS	
Worm (closed gear case)	Medium cylinder oil
Open gear case	Heavy oil
Shaft bearings (split or solid)	Oil or grease
Shaft bearings (ball or roller)	Machine oil or anti-friction bearing grease
Rocker bars and pins	Grease
CHAIN DRIVES	Gear oil or light grease
PULVERIZERS	
WORM GEAR DRIVE AND THRUST BEARINGS	Compounded cylinder oil
ROLLER JOURNALS	Light engine oil
SLEEVE BEARINGS	Oil or grease
ROCKER ARMS AND PINS	Grease
MILL FAN BEARINGS	Light engine oil
MOTORS AND FANS	
BEARINGS	
Sleeve	Light engine oil
Anti-friction	Grease
ECONOMIZER SCRAPERS	
Gears, chains and reversing mechanism	Adhesive gear compound

New York Power Show

It is announced that more than 250 exhibitors have already engaged space for the Thirteenth National Exposition of Power and Mechanical Engineering, to be held at Grand Central Palace, New York, during the week of December 5 to 10, which is concurrent with the Annual Meeting of the A. S. M. E. The exposition this year will occupy three floors of the building.

Among the numerous exhibits indicated by advance reports will be a number of sectionalized and working models of equipment, particularly that of one trap manufacturer who will show a working model of a complete boiler plant. The boiler will be electrically operated to generate steam at about 20 lb pressure, which will be reduced to 10 lb through a reducing valve and condensed at the rate of about 8 lb per hr. The condensate will flow through a trap having glass sides and be returned from an open receiver with a float-operated motor-operated pump.

Other working exhibits will illustrate boiler room instruments and controls, one of which will emphasize the extent to which the modern boiler room is controlled automatically.

Cover Photograph—The photograph on the cover of this issue was taken looking into an annealing furnace. The white object in the center is a pressure vessel on a car, which has been subjected to stress-relieving at 1900 F and consequently is aglow.

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At left:
One of three units for another station of the same company; 1455 g.p.m. each against 1186 lb.

Below:
The motor driven boiler feed and booster unit which was inspected; 660 g.p.m. of 300° F. water against 925 lb. at 1780 r.p.m., with 107 lb. pressure on the suction; one of six motor driven and six turbine driven De Laval units in the one station.

100% AVAILABILITY of

High Pressure Boiler Feed Pumps

Recently a central station having now in operation 12 modern

DE LAVAL *High Pressure* BOILER FEED PUMPS

dismantled one of the units for inspection and gaging of internal parts while the main unit served by it was down for inspection, after approximately three years of service. Although measurement of power input to these pumps is a routine matter and no appreciable change had been noted, the user wished to examine the clearances of wearing rings, shaft sleeves, diaphragm bushings and balance rings of the pump, which had been handling 300° F. water against a maximum of 925 lb. at 1780 r.p.m. almost continuously for around 25,000 hours.

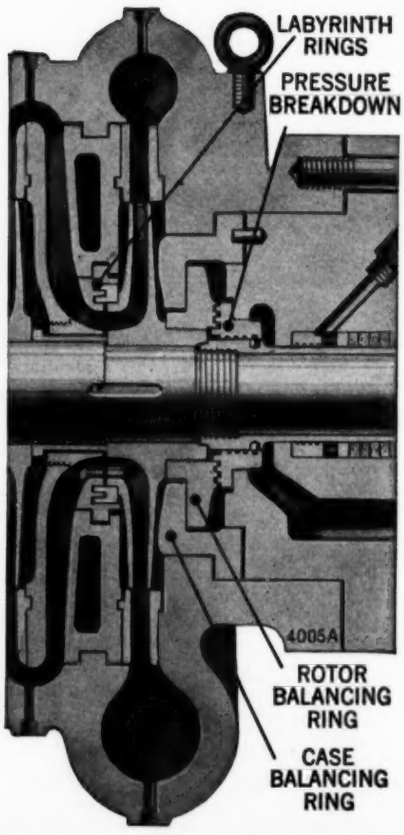
The examination showed that the original internal clearances remained practically unchanged, which explains why there had been no apparent falling off in pumping efficiency.

Particularly, the nitralloy balance rings of the automatic balancing device, which maintains axial balance hydraulically and makes a thrust bearing unnecessary, showed no evidence of erosion or wear.

There was no evidence of erosion of the casing around the balance rings or around the diaphragms, nor of the diaphragms themselves.

No wearing rings, balancing parts, shaft sleeves or bearings required renewal.

Send for our Book B-5 on self-balanced multistage pumps.



Sectional view showing last stage impeller and automatic balancing device.

3508

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TRENTON, N. J.

MANUFACTURERS OF STEAM TURBINES, PUMPS—CENTRIFUGAL, PROPELLER, ROTARY DISPLACEMENT; CENTRIFUGAL BLOWERS AND COMPRESSORS, WORM GEARS, HELICAL GEARS, HYDRAULIC TURBINES AND FLEXIBLE COUPLINGS • • • SOLE LICENSEE OF THE BAUER-WACH EXHAUST TURBINE SYSTEM

Residual Stresses Due to Circumferential Welds in Pipes

By E. L. ERIKSEN and I. A. WOJTASZAK
University of Michigan, Ann Arbor, Mich.

This is an abstract of a paper for presentation at the Annual Meeting of the American Welding Society, Detroit, October 16 to 21. The tests reported were made by the Department of Engineering Research of the University of Michigan and indicate the extent to which both circumferential and longitudinal residual stresses in circumferentially welded pipe are reduced by stress-relieving at 1200 F.

TESTS were made on a series of three welded specimens of 20-in. O.D. pipe having 1-in. wall thickness and four welded specimens of $8^5/_8$-in. O.D. pipe with $^1/_2$-in. wall thickness for the purpose of establishing the variation in the residual stresses produced primarily by stress-relieving, but also by other differences in the history of the specimens. The specimens were all 18 in. long and consisted of two 9-in. lengths of pipe joined by a circumferential electric arc weld; see Fig. 1. All were of open-hearth, seamless steel with a carbon content not exceeding 0.30 per cent. Three of the specimens were stress-relieved at 1200 F for 8 hr. A summary of the specimens follows:

Specimen No.	1	2	3	4	5	6	7
Pipe size (O. D.), inches	20	20	20	$8^5/_8$	$8^5/_8$	$8^5/_8$	$8^5/_8$
Wall thickness, inches	1	1	1	$^1/_2$	$^1/_2$	$^1/_2$	$^1/_2$
Stress-relieved	Yes	No	No	Yes	No	Yes	No

The circumferential residual stresses were determined first by laying out a number of rings on one side of the weld as indicated by the dotted lines 0–0′, 1–1′ . . . 5–5′ in Fig. 1. Reference marks were made at the ends

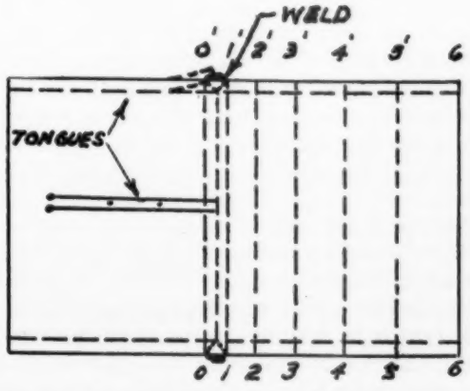


Fig. 1—Dotted lines indicate where rings were cut

of two perpendicular diameters of each ring (see Fig. 2) and its mean diameter found.

Next, circumferential residual stresses in the pipe were released by cutting it up into rings along the sec-

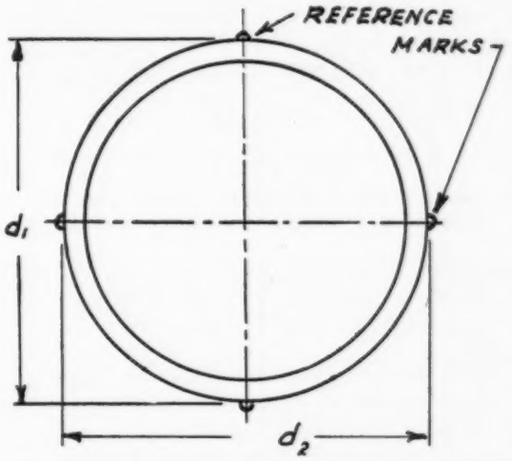


Fig. 2—Showing how mean diameters were determined

tions indicated by the dotted lines and the new mean diameter for each determined. The released stresses, either compressive or tensile, were then arrived at from the increase in mean diameter of the rings by the formula

$$S_1 = E\frac{\Delta d_m}{d_m}.$$

Where S_1 is the stress released by this means, E is the modulus of elasticity, Δd_m the increase in mean diameter of the ring and d_m its original mean diameter.

Further residual circumferential stress in each ring was found by cutting it open as indicated in Fig. 3. The stresses S_2 at the extreme fibers of the ring, released in this manner, are produced by a moment M, determinable by formula from which their magnitude was calculated.[1]

The total circumferential residual stress is then $S_1 + S_2$.

Determination of the longitudinal residual stresses is much more difficult and uncertain than that of the circumferential residual stresses. One can imagine a narrow ring including the weld and a portion of the pipe metal to be at the temperature of molten steel while the

[1] The original paper contains the several formulas and steps necessary for the calculations but these as well as later formulas are omitted here for brevity—Editor.

rest of the pipe is at room temperature. When this hot ring cools it will tend to shrink but, since it cannot shrink freely because of the adjacent pipe metal, it will set up longitudinal stresses due to bending of the pipe wall. The longitudinal stresses set up in this manner can be found by applying the theory of a beam on an elastic foundation.

In order to apply this theory to residual stresses in pipes due to welds, tongues were sawed in the walls of the the pipe, as indicated in Fig. 1, and readings were taken

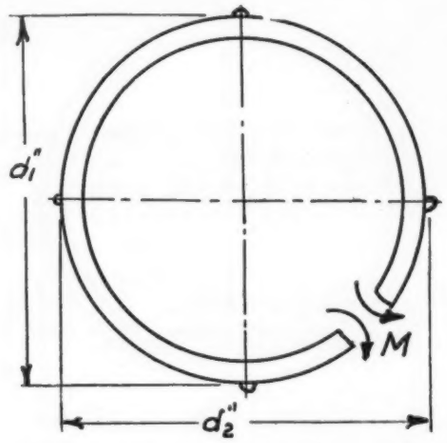


Fig. 3—Ring cut to determine further residual stress

to ascertain the amount of deflection at the free end of the tongue. From equations applicable to deflection of such a beam the longitudinal residual stress was determined.

In the laboratory procedure involved in this investigation all measurements were made with the aid of microscope micrometers reading to 0.001 mm.

The results are given in the following table.

RESULTS OF TESTS

No. of Specimen	Outside Diameter, Inches	Wall Thickness, Inches	Stress-Relieved	Maximum Longitudinal Stress, Lb per Sq In.	Maximum Circumferential Stress, Lb per Sq In.
1	20	1	Yes	± 8,500	4,000
2	20	1	No	±50,000	32,000
3	20	1	No	±45,000	26,000
4	8⅝	½	Yes	± 3,500	2,500
5	8⅝	½	No	±24,000	17,000
6	8⅝	½	Yes	± 5,000	3,500
7	8⅝	½	No	±25,000	13,000

± Indicates tension or compression.

Conclusions and Remarks

Probably the most important conclusion to be drawn from the results shown in the table is that the residual stresses are decidedly lowered by stress-relieving at 1200 F. It is to be remarked in this connection that tests by other investigators on 0.20 per cent carbon steel show that stress-relieving at 1200 F tends to increase the ductility about 50 per cent and lower the ultimate strength about 30 per cent.

It may be mentioned that the magnitude of the circumferential stresses given in the table is quite possibly more accurate than that of the longitudinal stresses. The circumferential stresses were obtained by simply transforming the elastic recoveries into stress, while a more complicated theory was assumed in the calculation of the longitudinal stresses.

It is also disturbing to the investigator to find longitudinal stresses of 50,000 lb per sq in., a stress that is beyond the yield point of the pipe material as well as the weld material. This may indicate that the calculations of the longitudinal stresses mean very little or it may mean that there has been quite a considerable stress locked up in the original pipe before welding or that a certain amount of strain hardening has taken place.

In order to get a more definite picture of the stresses set up by the actual welding process, it seems necessary that a much more comprehensive study should be made including an investigation of the original residual stresses in the pipe.

Finally, suppose the 50,000 lb per sq in. stress simply means that the material at some place has passed beyond the yield point. How serious this is will depend on the use of the pipe. If the pipe is subjected to steady or static stress, it will probably not be serious. If, however, the pipe is subjected to fluctuating stress so that the question of fatigue comes into play it may have serious results.

Pertinent Coal Statistics

Interesting figures concerning the bituminous coal industry for 1936 and 1937 are contained in a recent report of the Division of Research and Statistics of the National Bituminous Coal Commission, a few of which are here quoted.

The total production of bituminous coal in the United States for 1937 exceeded 442 million tons which represented a slight increase over 1936. Of this, 44,766,000 tons were consumed by the electric utilities and nearly twice that amount by the railroads. Exports, 90 per cent of which went to Canada, were 13 million tons, whereas imports were only 258,000 tons.

In 1937, 45 per cent of the total national energy supply was furnished by bituminous coal. Increased competition from oil and gas was experienced. Although the coal consumption for power generation, steamships and railroads increased 3 per cent over 1936, the competitive use of oil by these classes of consumers combined increased 10 per cent, and in the domestic field the sales of oil burners were twice those of stokers.

The quantity of bituminous coal produced by stripping rose to a new level of over 28 million tons in 1936, an increase of 19 per cent over 1935, and further increases in stripping were indicated for 1937 in Illinois and Indiana.

In underground workings 84.5 per cent of the production was cut by machines and a continued growth in the installation of mechanical loading devices, as well as mechanical cleaning of the coal, is reported.

The men employed in bituminous coal mining during 1937 numbered 484,000, and the mines operated an average of 199 days out of the 261 days possible under the 5-day week of the union wage agreement. Under this agreement the potential capacity of the mines operating would have been 576 million tons.

The trend toward a shorter working day is shown by a comparison of 1903 with 1936. During the former year none operated on a 7-hr day, 56.4 per cent worked 8 hr, 17.9 per cent 9 hr and 26.5 per cent 10 hr, whereas in 1936, 97.6 per cent of the mines operated on a 7-hr day, 2.3 per cent on an 8-hr day and only 0.1 per cent on a longer day.

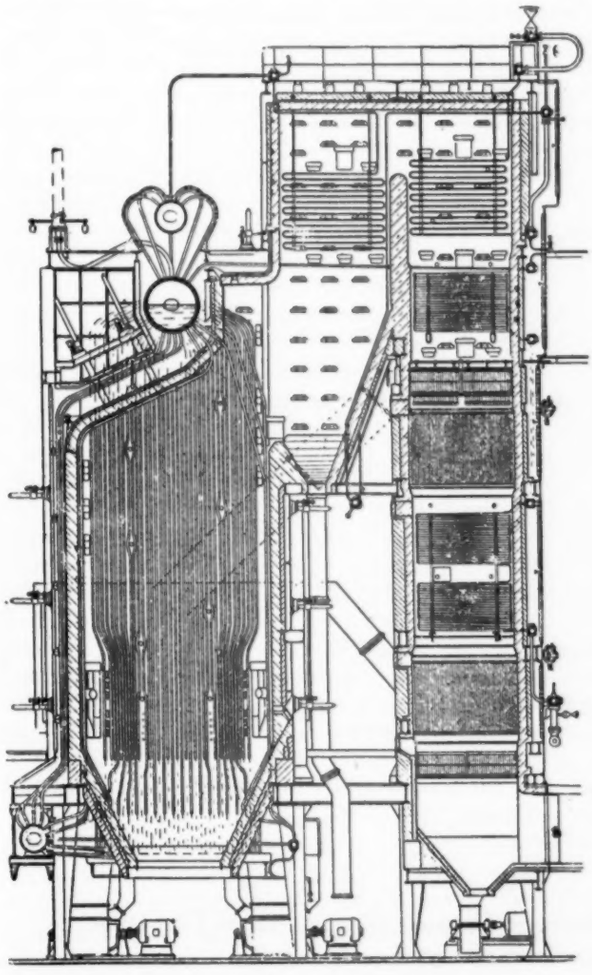
STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Radiation Boiler

Die Wärme of June 25 contains an article by F. Schulte and F. Wentrup discussing German boiler practice. Among the several boiler types illustrated was one of a Buckan radiation boiler designed for high pressure service. This is reproduced herewith.

The unit has a maximum rated capacity of approximately 180,000 lb of steam per hour at 1780 lb pressure and 932 F total steam temperature. It will be noted that all the evaporation takes place in the water walls,



Cross-section through Buckan radiation boiler

there being no boiler surface in the ordinary sense of the term, and these water-wall tubes all enter the drum directly. Outside downcomers return the water from the drum to the lower water-wall headers. A dry drum is provided and the superheater is in two sections. Corner firing of pulverized coal is employed.

Of special interest is the distribution of heat recovery surface, the economizers and the air heaters each being divided into two stages which are alternated. That is, the gases after leaving the second stage of the superheater pass to the first-stage economizer, thence to the first-stage air heater, the second-stage economizer and finally the second-stage air heater, in the order named. Each air heater stage is divided into two sections, the first section of the first stage being of cast heat-resisting alloy and the second section of the last stage being of cast corrosion-resistant metal.

Incidently, the article states that there are around two hundred boilers in Germany operating at pressures above 1130 lb per sq in.

An Unusual Tube Failure

The Engineer of August 12 reviews the British Board of Trade Surveyor's report on an unusual tube failure in a straight-tube sectional-header boiler operating in a chemical works at Ilford. The tube that failed was the third from the left side in the second row from the bottom. It opened for a length of $5^1/_2$ ft and scalded one of the operators. Examination revealed a thinning of the bottom of the tube for a considerable portion of its length due to external erosion. This erosion was traced to the position of the soot blower and the angle of the rear edge of the jet orifice in relation to the side wall of the furnace, these being such as to cause scouring of the refractory lining. The consequent impingement of the stream of grit, resulting from local disintegration of the wall and deposited ash, caused abrasion along the bottom of the tube.

The boiler was fired with coke breeze and some difficulty had previously been encountered with ash formations of the bird-nesting type. The regular soot blower had been unable to deal effectively with this ash, hence it was blanked off and a single-nozzle design substituted. This was operated every four hours. It had been installed correctly but subsequent distortion of its mounting had altered the angle of the steam jet so that it impinged on the brickwork and was deflected onto the tube that became eroded.

Scale Formation in Ramsin Boiler

The Steam Engineer (London) for August contains a discussion of scale formation in the Ramsin once-through boiler,[1] based on a translation from Russian of articles by Ramsin, Kovalchuk and Patsukov in *Sovetskoe Kotloturbostroenie.* These observations are based on

[1] For a description of this boiler and a diagram of its circulation, see COMBUSTION, July 1938 and October 1936. It is of the drumless type and has become an accepted standardized design in various sizes by the Soviet government.

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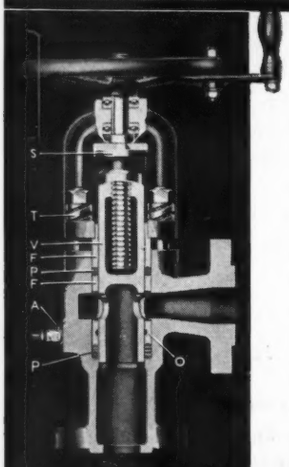

Yarway Seatless Blow-off Valve. Operation: After Valve is closed, shoulder S on plunger V contacts with upper follower gland F, forcing it down into body and compressing packing P above and below port. Annular groove O connects with Alemite fitting A for lubricating plunger and packing. Yoke springs T maintain continuous pressure through follower gland F on packing rings P.

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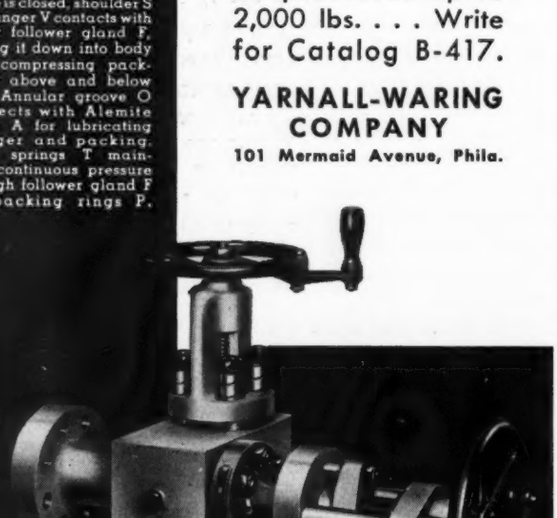

Yarway Unit Tandem Blow-off Valve for pressures from 600 lbs. to 1500 lbs. A Seatless and Hard Seat Valve combination using a common forged steel body.

YARWAY

BLOW-OFF VALVES

experience with two boilers that have been in service for many months in Moscow.

According to the authors, a certain amount of scale formation cannot be avoided with this type of boiler even when fed with condensate containing as low as 0.4 grains per gallon of soluble salts. The solution of the problem was found in feeding the boilers with condensate, washing them from time to time with ordinary water and resorting to chemical washing at longer periods. So far hydrochloric acid has generally been employed for this purpose but chromic acid is being considered.

Experience has shown that fully 50 per cent of the solids are not deposited within the boiler and of the total deposited the greatest portion was sufficiently soluble to be washed away by the circulation of water, consequent upon the shutting down procedure. In a test run of 4433 hr with feedwater containing 0.7 grain per gallon, out of 3660 lb of solids introduced into the boiler only 150 lb, or about 4 per cent, was left on the tubes. The greatest portion of the solids was deposited in the evaporation zone although other tests indicated that the distribution of scale depends on the solubility of the salts. For instance, the very soluble compounds are deposited in the evaporation zone and low concentrations of calcium and magnesium of less solubility are more uniformly distributed over the different heating surfaces. Feedwater softening tends to localize the scale in the evaporation zone.

Of the several salts, sodium sulphate appears to be the greatest offender. Not only was it precipitated in greater percentages than other salts but its presence actually resulted in heavier precipitation of caustic soda. Sodium chloride deposited in small amounts up to a content of 1 grain per gallon above which the quantity precipitated rose sharply.

Corrosion was confined almost entirely to the economizer section of the unit, with a few tubes in the evaporation zone, unprotected by scale, showing pitting to a depth of 0.02 in.

With reference to washing with hydrochloric acid, this must be used in the presence of an inhibitor, such as common glue, inasmuch as it will attack steel. Chromic acid, while not attacking the steel appreciably and therefore usable without an inhibitor, is more expensive and must be handled with care as it attacks the skin and mucous membranes. Furthermore, a higher temperature and greater concentration must be employed with chromic acid than in the case of hydrochloric acid. With the latter a 3 per cent concentration at 120 to 140 F and 4 hr duration will suffice whereas with the former a 4 per cent concentration at 195 to 205 F and 10 to 15 hr are required.

Survey Shows Shortage of Engineers in Germany

In order to check the belief that Germany is faced with a potential shortage of engineers, a survey of enrollment in engineering courses and other fields has been made by the VDI, the results of which are discussed by C. Welkner in *Zeitschrift des Vereines deutscher Ingenieure* of June 4, 1938.

This study revealed the number of engineering students in the technical high schools to be about 44 per cent of

that in 1928 and in the universities about 52 per cent. The various branches of engineering taken up by students entering in 1936 (based on 100 per cent for 1928) were: Mechanical engineering, 41.7 per cent; electrical engineering, 19.8 per cent; architecture 21.9 per cent; chemistry, 53.7 per cent; marine and aeronautical engineering, combined, 97.5 per cent.

On the other hand, the figures for medicine are 179 per cent, for theology 167 per cent and for political economy 65 per cent. This leads to the assumption that there is a trend toward preparation for those callings which offer an independent living.

However, the percentage of students passing the final examinations shows an increase during this period, which would indicate either improved scholarship or possibly a letting down of the requirements for graduation. Despite this, an extension of the curves to 1940 indicates that the new engineering graduates will number only about 37 per cent of the average for the years between 1929 and 1935. The average yearly graduates in mechanical engineering for 1929 to 1931 was approximately 1000; for 1937 about 600 and for 1938 to 1940 only 300. For electrical engineering the figures are, respectively, 650, 500 and 120.

It is estimated that in 1933 there were approximately 250,000 engineers of all kinds in Germany, of which 18.2 per cent were between the ages of 25 and 30; 31.4 per cent between 30 and 40; and 21.1 per cent between 50 and 60. Yearly replacements are figured normally at 4000 to cover deaths, retirements, etc., although this 1933 figure should increase due to the fact that many older engineers are still in active service because of the shortage of younger men and will soon be unavailable. Added to this are the requirements to take care of technological advancements, estimated at 6000 engineers, making a total yearly requirement, according to the survey, of 10,000 engineers. The present output of engineering schools will fall far short of meeting this demand.

In an effort to meet this situation and induce more young men to take up the study of engineering, financial assistance for those lacking the necessary funds is being offered by manufacturing groups, the VDI and a student works program of the government.

Large Single-Casing High-Pressure Turbine

The first 1200-lb condensing turbine-generator of 80,000 kw capacity to be built in a single casing has been ordered by the Central New York Power Corporation, a subsidiary of Niagara Hudson Power Corporation, for the new power station at Oswego. This unit, of General Electric design, will be 53 ft overall, 13 ft high and weigh approximately 500 tons. It will receive steam at 1250 lb, 900 F from a single boiler and will run at 1800 rpm. Previous 1200-lb condensing units have been of the tandem-compound or cross-compound types and most of the recent units for this pressure have been non-condensing machines running at 3600 rpm. Buckets and nozzle partitions will be of stainless steel. The generator will be hydrogen cooled.

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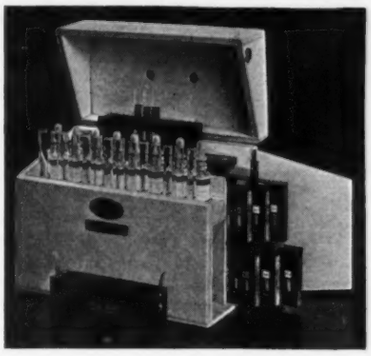

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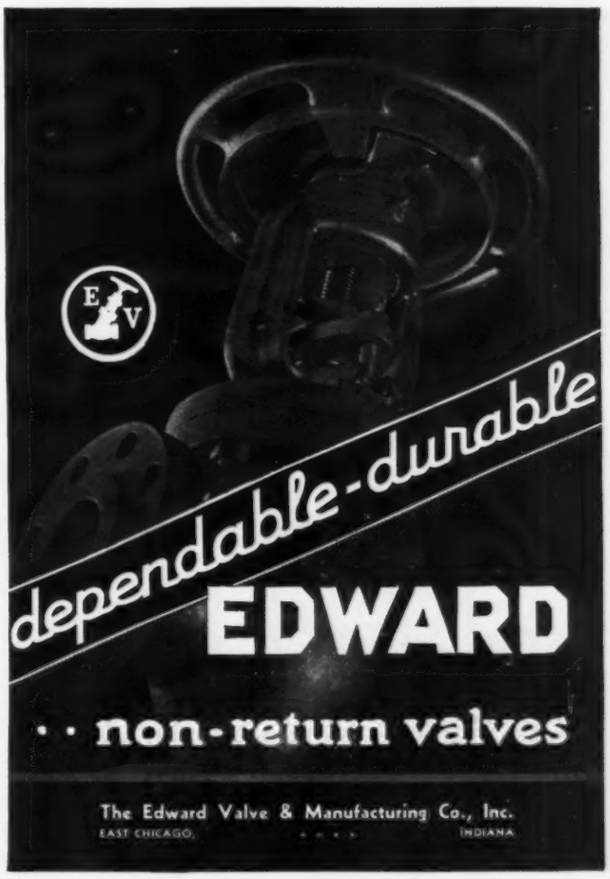


REVIEW OF NEW BOOKS

Any of the books reviewed on this page may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Steam and Gas Engineering

By T. E. Butterfield, B. H. Jennings and A. W. Luce

This is the third edition, the first having been brought out in 1929 and the second in 1933. That three editions should have been found necessary in the course of nine years typifies the progress and changing practice in this field. The present book contains extracts from the new Keenan and Keyes steam tables, up-to-date descriptive material on power plant equipment and devotes considerable space to steam cycles, high pressures and high temperatures, as found in the modern power plant. There are also chapters devoted to the internal combustion engine as well as fuels, combustion and fundamental thermal considerations.

Prepared primarily for use as a textbook for students in steam and gas engineering, the book is free of higher mathematics and should prove useful to many engineers in practice, particularly those who have not kept in intimate touch with recent power plant practice.

There are 490 pages, 6 × 9 in., and over 300 illustrations; price $4.50.

Diesel Engines

By B. J. von Bongart

The author, who is a consultant in the field of diesel engines, predicates the text on a review of early researches in the field of internal combustion engines leading up to the work of Dr. Diesel in 1892. This is followed by the development of the diesel engine up to its present state. Designs of diesel engines as adapted to various fields of application are described and discussed. Chapters on thermodynamics, combustion, fuel oils, atomization, fuel pumps, fuel injection nozzles, combustion chamber design and supercharges are included. The economics of the diesel engine are also discussed and much research is reviewed.

The book should prove useful to all who desire to become familiar with the present status of this type of prime mover. It contains 335 pages, fully illustrated, with cloth binding; price $5.50.

Test Code for Fans

Distribution is now being made of the third edition of the "Standard Test Code for Centrifugal and Axial Fans," published by the National Association of Fan Manufacturers, General Motors Building, Detroit. This Code is sponsored jointly by the American Society of Heating and Ventilating Engineers and the Association with cooperation from Committee No. 10 of the Power Test Code Committee of the American Society of Mechanical Engineers. The third edition includes clarifications of definitions; finite statements concerning the several methods of testing as applied to various types and arrangements of fans; the addition of egg crates or straightening vanes to ducts; a reduction of the allowance for duct friction; and modification of the Pitot tube. The price is 25 cents.

Welding Handbook

This 1200-page handbook, published by the American Welding Society, represents the work of 90 authors, each a specialist in a particular branch of the field, and 250 reviewers. It is a comprehensive treatment of this important subject. Among the subdivisions of the text are fundamentals of arc welding, shielded arc welding, automatic carbon arc welding, fundamentals of gas welding, atomic hydrogen welding, resistance welding, spot welding, thermit welding, oxygen cutting, arc cutting, preparation of surfaces, metal spraying, welding control, materials and metallurgy, testing welds and various welding applications. A digest of welding literature is appended.

The book, bound in attractive imitation leather, represents the most authentic and up-to-date treatise on welding that has yet appeared. With welding now employed in so many diversified fields of production and operation the handbook should find a wide demand among engineers.

The price in this country is $6 ($5 to members of the Society) and $6.50 in foreign countries.

Fatigue Test of Riveted Joints

By W. M. Wilson and F. P. Thomas

This is a pamphlet issued by the Engineering Experiment Station of the University of Illinois, Urbana, Ill., giving the results of recent investigations on the fatigue strength of riveted joints connecting structural steel plates.

In the specimens tested all the rivets were in double shear and all had a nominal diameter of one inch. Some specimens were designed for rivet failure and others for plate failure. The variables studied included the grip of the rivets, the relation between unit shear, unit bearing and unit tension; the transverse distance between rivets, combinations of carbon-steel and manganese-steel rivets with carbon-steel, silicon-steel and nickel-steel plates, as well as the methods of making the rivet holes.

Free distribution of this pamphlet, No. 302, is being made until February 15, 1939.

NEW EQUIPMENT

Air Ratio Meter

A new direct reading ratio meter has been announced by the Askania Regulator Company. This consists of two flow metering elements, one for air and one for gas. The pointers shown are arranged to cross in the chart area so that the intersection of the pointers indicates the rela-

tion between the two flows. As long as the pointers cross on the vertical or zero line, it shows that a neutral flame is being maintained. If they cross in the area to the right, it will show the percentage of excess air. Conversely, as the pointers cross in the deficiency area, it will show the air deficiency.

The ratio meter may be used on all types of heating equipment whether they are equipped with automatic fuel-air ratio control or manually operated. It shows at a glance the relationship between fuel and air.

Automatic Control for Reeves Drive

Reeves Pulley Company has developed a mechanical automatic control for its "Motodrive," which makes possible synchronization of different machines and separate sections of a single machine; maintenance of constant tension and uniform peripheral winding speeds; and maintenance of uniform pressure, weight, liquid level, temperature and other variable elements.

On the motor (constant speed) shaft of the Motodrive is a cover plate including a lever bracket and extended lever which may be attached by cable or chain or direct to a compensating or floating roll (where properly balanced by weights), pressure regulator, moving carriage or part of machine, etc., from which indication of required speeds can be taken. Movement of the lever is transmitted to the speed changing mechanism of the Motodrive to change its speed in accordance with the indicating movement, thus providing the advantages in automatic control cited. Travel of the lever in either direction is limited by stop screws. The lever may be of any length, as required by the installation, and may be assembled in any one of four different positions. The control is available for all five sizes of Motodrive, in both horizontal and vertical designs.

CO Detector

A new device for ascertaining the carbon monoxide content of any given air space has been perfected by the Engineering Department of the Travelers Insurance Company.

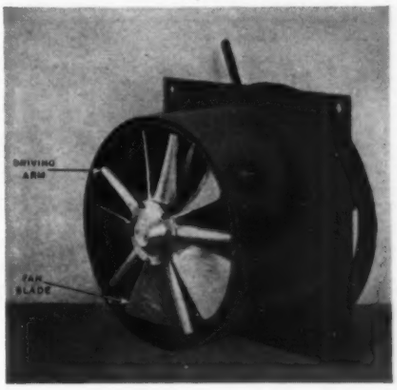
The device depends upon the conversion of carbon monoxide into carbon dioxide by combustion and the reaction of this carbon dioxide with an earth-alkali hydroxide, using phenolphthalein as an indicator. By means of an ordinary bicycle pump, the atmosphere to be tested is drawn through a filter, removing all carbon dioxide and hydrocarbons from the air. The carbon monoxide, remaining unchanged, is then converted to carbon dioxide by drawing it over an ordinary cigarette lighter coil. The product is then bubbled through the alkali solution. With the capacity of the pump known, it is only necessary to count the number of strokes until the color of the solution disappears. By referring to a table computed on the basis of carbon monoxide concentrations that are negligible, slightly harmful, and dangerous, with finer gradations between these divisions, the amount of carbon monoxide in the tested atmosphere is ascertained to a degree of accuracy sufficient for all practical purposes.

The Travelers will follow its usual policy of making the specifications and instructions available to anyone interested in promoting safety and the welfare of those who might be exposed to poisoning by carbon monoxide.

Rotary Gas Burner

Coppus Engineering Corporation has introduced a new line of gas burners of the rotary type, consisting primarily of a fan with a long hub in which two ball bearings are mounted, so that the fan rotates on a stationary shaft which serves at the same time as the gas inlet pipe. The gas is admitted through the hollow shaft and enters the fan hub. The fan has several air blades as well as driving arms. The gas flows into these arms, leaves them through small orifices and, by reaction, causes the fan to rotate at high speed. The fan blades then act as any other power driven fan, delivering air for combustion. As the air flows in a direction parallel to the shaft and the gas flow is in a plane practically at right angles to the air flow, a very thorough mixture of gas and air is obtainable directly at the fan.

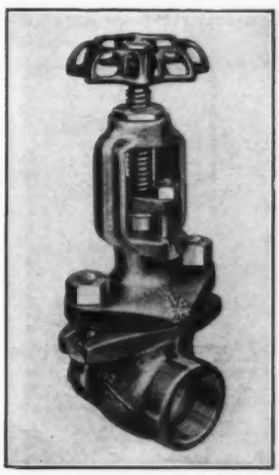
The number of orifices in the driving arms as well as the gas pressure determines



the total amount of gas flow and its reactive force determines the speed of the fan and hence the air delivery. The fan can be therefore designed so that there will be the desired ratio between gas and air. If a lower rating is desired, the gas pressure is reduced, decreasing the total amount of gas flow and also causing the fan to slow down, thereby reducing the air volume.

Stainless Steel Valves

Jenkins Bros. has lately introduced a line of corrosion-resisting stainless steel valves designed for most severe conditions and particularly adapted to sulphite pulp mills. They are available in seven different styles, namely, solid wedge or double



disk gate valves, union bonnet or bolted bonnet regrinding globe or angle valves, and bolted bonnet "Y" valves; all either screwed or flanged, in sizes $1/2''$ to $3''$.

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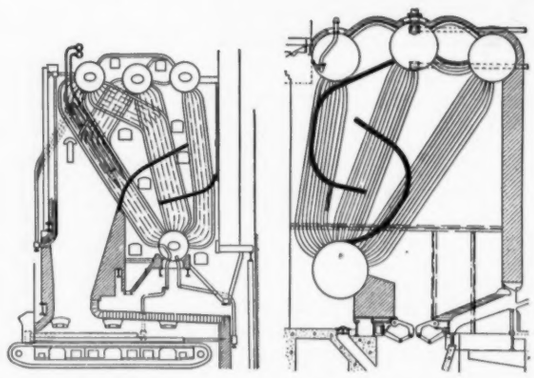

Bulletin B-37 describes in detail The Construction of Enco Baffle Walls and Their Application to Modern Boilers and the Modernization of Existing Plants.
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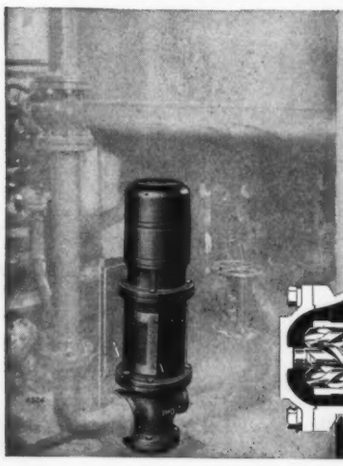

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